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PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES INDIA

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March, 1939

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INDIGOID DYESTUFFS DERIVED FROM CHRYSOQUINONE

BY VISHWAJIT LAL VARMA AND SIKHIBHUSHAN DUTT

CHEMISTRY DEPARTMENT, UNIVERSITY OF ALLAHABAD

Received March 29, 1938

SUMMARY

1. Like phenanthraquinone, chrysoquinone also condenses with aromatic phenols and other similar substances with formation of indigoid dyestuffs.
2. The condensations take place in presence of acetic anhydride and a small quantity of concentrated sulphuric acid.
3. The condensation products are dark brown or black in colour and dissolve completely in alkaline sodium hydrosulphite with formation of dark brown solutions.
4. Cotton is weakly dyed to light brown or grey shades from the highly sulphite vat apparently due to the poor affinity of the cotton fibre for the dyestuff.
5. The freshly precipitated dyestuffs dye wool much better and deeper shades from a bath acidified with dilute acetic acid.

Chrysene is one of the rare hydrocarbons of coal tar occurring in the higher boiling fractions which pass over between 430° — 470° C. In the crude state it has got a golden-yellow colour (chryso = golden-yellow) and the nauseating odour of hot pitch. But when carefully purified *via* the picrate it becomes converted into an almost odourless mass of silver-white leaflets with a pale violet fluorescence.

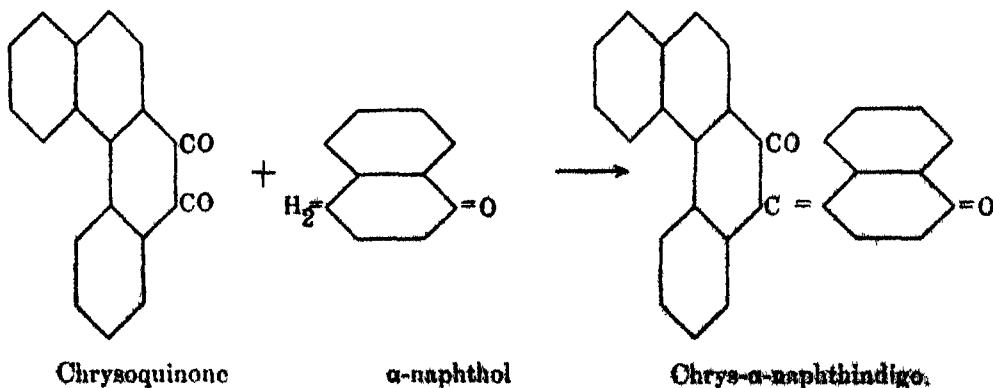
There is at present no technical or commercial use for chrysene, although it is present in the higher boiling fractions of coal-tar and also in pitch in quite high proportions. Naturally it can be expected that if some technical utility could be devised for this substance, it would indeed be a very important thing from the scientific as well as from the commercial point of view.

The constitution of chrysene has been established as naphth-phenanthrene, and like phenanthrene on oxidation it yields a very interesting substance, chrysoquinone, which is an alpha-diketone. In a previous investigation, Singh and Dutt⁶ have already shown that anilinoderivatives from chrysoquinone as well as condensation products of chrysoquinone with aromatic amines have got interesting tinctorial properties, and many of them dye wool from an acid bath and cotton from a hydrosulphite vat in the same way as the corresponding dyes derived from phenanthraquinone prepared by Mukherjee and Watson.⁴ In view of Friedlander's¹ work on Ciba Scarlets and their derivatives obtained from aromatic o-diketones by condensation with other secondary constituents such as resorcinol, α -naphthol, 1:5-dihydroxy-naphthalene, 2-hydroxy-thionaphthene, &c., and also Friedlander and Bezdzig's^{2, 3} work on similar lines, it was naturally expected that perhaps chrysoquinone also would yield similar indigoid derivatives on condensation with appropriate secondary constituents. This expectation has been realised and chrysoquinone has now been successfully condensed with the following secondary constituents :

α -naphthol, β -naphthol, catechol, resorcinol, pyrogallol, phloroglucinol, 1:4-dihydroxy-naphthalene, 1:5-dihydroxy-naphthalene, thiohydantoin, 1:3-diphenylthio-barbituric acid and 2-hydroxy-thionaphthene.

The condensation products mentioned above are very dark-brown and in many cases black substances which are soluble in alkaline hydrosulphite vat and dye cotton to somewhat light shades of brown and grey, due apparently to the poor affinity of the dyestuff for cotton. When freshly precipitated from strong sulphuric acid solution, they however impart much better and deeper shades on wool from an acid bath. The absorption maxima of these dyestuffs have been appended at the end of the paper in a tabular form.

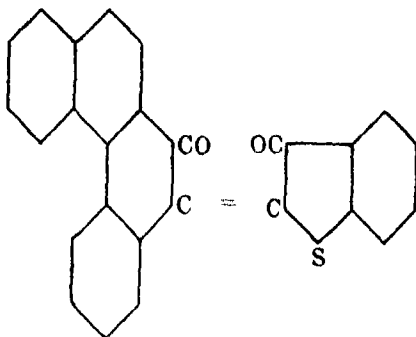
The condensation of chrysoquinone with secondary constituents takes place in presence of acetic anhydride and concentrated sulphuric acid in the following manner, with formation of indigoid derivatives :



EXPERIMENTAL

Preparation of chrysoquinone :—5 grams of chrysene in fine powder was taken in a 500 c.c. flask, to which a solution of 22 grams of sodium dichromate in 50 c.c. of glacial acetic acid was added. The mixture was refluxed for about 9 hours when the colour of the product changed to dark green, and about 50 percent of the total yield of chrysoquinone crystallised out. While still hot, the reaction mixture was added to an equal volume of hot water, when the separation of the quinone was complete. The quinone was washed free from chromium salts first by dilute hydrochloric acid and then with water. After drying in the steam oven, the product was crystallised from glacial acetic acid in glistening orange-red needles, melting at 239°C. Yield, 5.2 gms.

Chrysthioindigo :—



A mixture of chrysoquinone (2.58 gms.), 2-hydroxy-thionaphthene (1.46 gms.), and acetic anhydride (80 c.c.) was treated with concentrated sulphuric acid (1 c.c.) and the mixture refluxed for two hours on a sand bath, when a black precipitate of the chrysthioindigo separated out from the hot solution. This was filtered off, washed several times with alcohol and water and dried in the steam oven. It was next crystallised by solution in a mixture of nitrobenzene (1 part) and glacial acetic acid and gradual addition of ether to the solution. The crystalline precipitate was washed free from nitrobenzene first by means of alcohol and then with ether. It crystallises in black microscopic needles and is fairly soluble in nitrobenzene, pyridine and aniline, but only very slightly soluble in other organic solvents. It does not melt up to 310°C. It dyes wool deep grey from an acid bath and cotton light grey from an alkaline hydrosulphite vat.

Other condensations of chrysoquinone were carried out in a similar manner using a mixture of acetic anhydride and concentrated sulphuric acid as a condensing agent. The products were purified and crystallised as indicated above. All these indigoid dyestuffs are soluble in nitrobenzene, aniline and pyridine, but almost

Table 1

Properties of indigoid dyestuffs derived from Chrysoquinone

Chrysoquinone condensed with	Appearance of the product	Colour in pyridine solution	Absorption maximum in pyridine (λ)	Shade of dyeing on wool (acid bath)	Shade of dyeing on cotton (hydrosulphite Vat)	Analysis % (theoretical values within brackets)
α-naphthol	Dark brown microscopic needles.	Dark brown.	4980	Deep yellow-brown.	Light brown	C = 87.27 (87.4) ; H = 4.16 (4.16).
β-naphthol	" "	"	4950	"	"	C = 87.2 (87.4) ; H = 4.2 (4.16).
Catechol	Black needles	Brown	5230	Nut-brown	"	C = 82.0 (82.3) ; H = 4.0 (4.0) .
Resorcinol	" "	Dark brown.	5120	Light tan	Light tan	C = 82.07 (82.3) ; H = 3.9 (4.0) .
Pyrogallol	" "	"	5150	"	"	C = 78.2 (78.4) ; H = 3.76 (3.8) .
Phloroglucinol	" "	"	5330	"	"	C = 78.27 (78.4) ; H = 3.52 (3.8) .
1:5-dioxynaphthalene	Dark brown prisms.	"	4970	Greyish-brown	Light grey	C = 83.9 (84.0) ; H = 3.79 (4.0) .
1:4-dioxynaphthalene	" "	"	4990	"	"	C = 83.7 (84.6) ; H = 4.2 (4.0) ; S = 8.7 (8.8) .
Thiohydantoin	Black needles	"	5130	Leather-brown	Greyish-brown	S = 5.7 (5.95).
1:3-Diphenylthiobarbituric acid.	Dark brown	"	4920	Light-brown	Light grey	
2-Oxythionaphthene	Black needles	"	5130	Dark tan	Light tan	C = 79.4 (80.0) ; H = 3.21 (3.6) .

insoluble in other organic solvents. None of them have any melting points. They have very interesting dyeing properties and impart various shades of grey and brown to wool from an acetic acid bath, and similar but lighter shades on cotton from an alkaline hydrosulphite vat. For the sake of abbreviation, the properties of these indigoid dyestuffs derived from chrysoquinone have been given in a tabular form in the previous page.

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5. Singh and Dutt (1938) *Proc. Ind. Acad. Sci.*, **8**, 187.

F-REGION IONIZATION IN JUNE 1938 AT ALLAHABAD

By K. B. MATHUR AND G. R. TOSHNIWAL

PHYSICS DEPARTMENT, UNIVERSITY OF ALLAHABAD

Received October 29, 1938

SUMMARY

The paper deals with the determination of the critical penetration frequency of the F_1 -region during the Summer Solstice period, 1938. The mean of these observations shows that the ionization begins to increase an hour after the ground sunrise and it attains its maximum value of 14.7 Mc/Sec (2.67×10^9 electrons per c. c.) at 17 00, i.e., two hours before ground sunset.

INTRODUCTION

The data collected in our laboratory since 1927 distinctly pointed out to the desirability of using frequencies lying in the neighbourhood of 4 Mc. for broadcasting in India. The same view has been taken by the International Telecommunication Conference held at Cairo in February, 1938, and a frequency band lying between 4770—4900Kc. has been reserved for broadcasting in the tropical countries.

In order to organise a reliable broadcasting service throughout the year it is, however, necessary to have a thorough knowledge of the Ionosphere. So far due to lack of funds it was not possible to purchase necessary equipment to enable us to study the ionization density of the F_2 -region in midsummer, when the disturbances are fairly great and absorption very high. The present paper gives the ionization density measured at Allahabad a few days before and after the summer solstice.

EXPERIMENTAL RESULTS

The transmitter used in the present studies has been described elsewhere.⁴ The receiver, however, was a new one. In addition to one stage preselector, there were two 460 Kc. intermediate stages, the a. v. c. was cut off and the circuit after the second detector was altered so that the first audio stage could be used as a d. c. amplifier. The observations were taken visually on the cathode ray oscillograph.

The frequency of the transmitter was varied continuously with one hand, while with the other hand the receiver was kept in tune with the transmitted frequency, so that the echo was visible throughout till the penetration frequency (f_o^x) was reached. The critical frequency of the ordinary ray could always be accurately found out, but owing to large absorption and high level of disturbances the critical frequency of the extraordinary ray was usually dubious. The results obtained are given in figures 1, 2 and 3.

Figure 1 shows the variation of critical penetration frequency on the 19th, 20th, and 21st of June, 1938.

19th June:—There is a steep increase between 06 00 and 07 00 after which the ionization goes on gradually increasing. The critical penetration frequency was

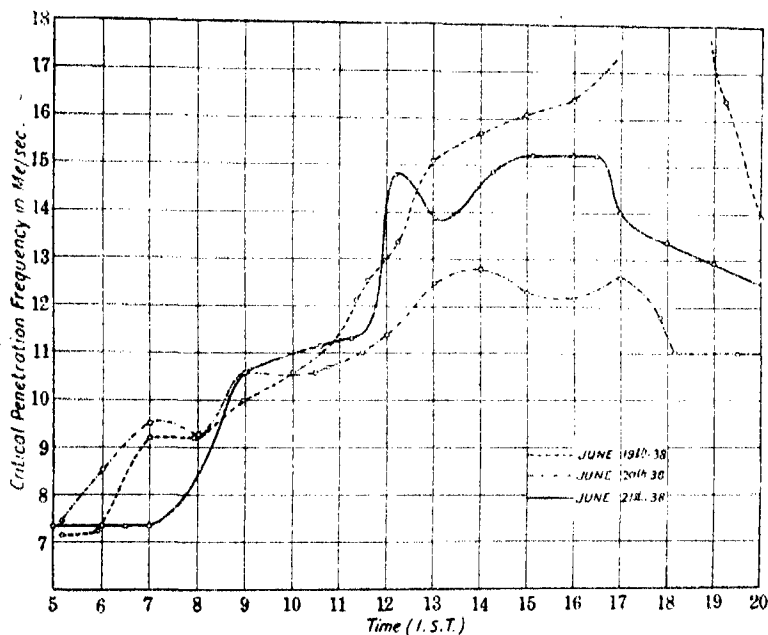


Fig. 1

more than 18 Mc. between 17 00 and 19 00. The upper limit though very close to 18 Mc. could not be determined as the receiver was not designed to receive higher frequencies.

20th June:—There was a rapid increase in ionization between 05 10 and 07 00. Between 08 00 and 09 00 there was again a steep rise, but after about 10 00 the increase in ionization was gradual. There were two maxima one at 14 00 and the other at 17 00.

21st June:—The critical frequency was constant up to 07 00 after which there was a rapid increase up to 09 00. A second steep increase was noticed between 11 10 and 12 10. The critical frequency being 14.8 Mc. the f_oF_2 fell down to 13.9 Mc. at 13 03, then it gradually rose to 15.2 Mc. and remained constant at this value till 16 30. At 17 00 it suddenly fell down to 14 Mc.

Figure 2 shows the critical frequency measurements for 22nd, 23rd, 24th and 25th June, 1938.

22nd June :—The curve is very much similar to the one for the 19th June. There was very steep rise between 15 30 and 16 24 and a very steep fall in ionization between 18 42 and 20 00. Between 16 24 and 18 45 the critical frequency was greater than 18 Mc.

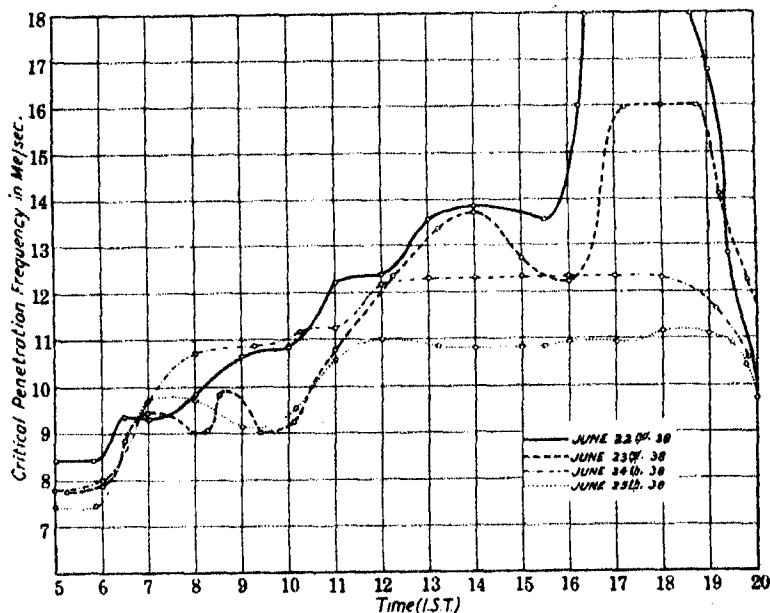


Fig. 2

23rd June :—There was a steep increase in ionization between 06 00 and 07 00; 08 15 and 08 30; and 16 00 and 17 12. A steep fall was observed between 18 50 and 20 00. There were four maxima and the highest critical frequency was 16 Mc. observed between 17 12 and 18 50.

24th June :—A steep increase in the value of f_o^X was noticed between 06 00 and 08 00, after which the critical penetration frequency increased gradually to 12.2 Mc. at noon and remained almost constant up to 18 00.

25th June :—There was one broad maximum between 07 00 and 08 00. The value of f_o^X remained almost constant between noon and 19 30.

Figure 3 shows the average of the seven days' observations. The curve shows a gradual rise in ionization after about 05 30 with a maximum at about 17 00. Between 16 00 and 19 00 the curve has been obtained assuming that during these hours on the 19th and 22nd June, the critical penetration frequency was 18 Mc. But

actually the critical frequency was higher than 18 Mc. This will naturally increase the maximum value in the curve, but the general form of the curve will remain the same.

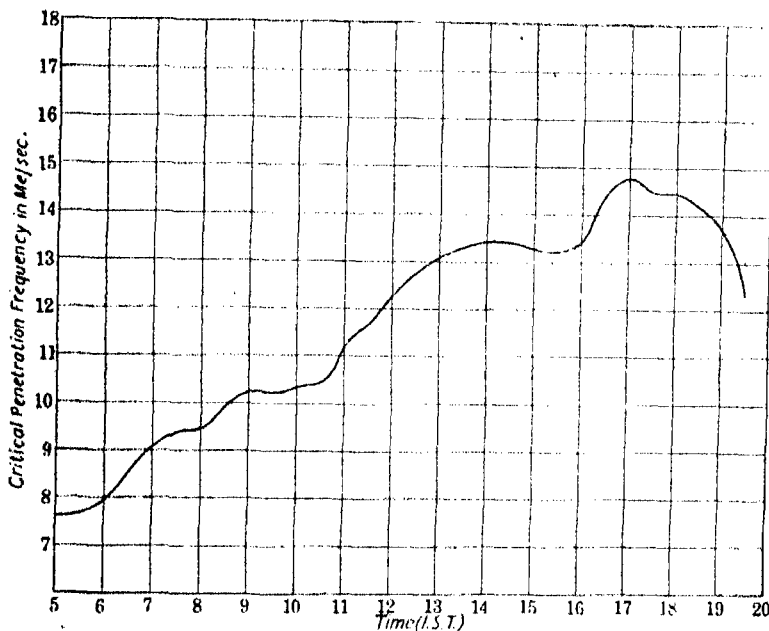


Fig. 3

DISCUSSION OF THE RESULTS

The curves if examined individually show that there is a maximum of ionization near about 07 00 after which there is a little fall, which appears to be a regular feature. This seems to be due to attachment of electrons to the oxygen atoms.¹ However, later on the ionization again increases by large amount. It seems that at this stage the dissociation has proceeded to such an extent that all the molecules have split up into atoms, but the ionization is still vigorously going on, so that the rate of increase in ionization is greater than the rate of attachment.

The after-noon curves for the 24th and the 25th June are almost similar to those obtained in October and November by Bajpai and Pant,² except that in their case the ionization was nearly constant from about 08 30 while here the ionization does not vary much in the after-noon.

The average curve, shown in figure 3, is similar to that obtained for whole of June 1938 at Washington.³ The maximum value of f_oF_2 at Washington was 8.7 Mc. at 19 30, while we have a maximum at about 17 00, the f_oF_2 being 14.7 Mc. (267×10^6 electrons per. c.c.). Our maxima are usually near about 17 00, i.e., nearly two hours before ground sunset, while at Washington the maxima are found to be near sunset.

Another point of difference between the curves obtained at the two places is that at Washington the ionization in the F_2 -region begins to increase at the time of ground sunrise, while at Allahabad it does so an hour after sunrise.

Our hearty thanks are due to Prof. M. N. Saha, F.R.S., for his keen interest and encouragement, and for the large amount of money that he gave us out of his personal research grant given to him by the Government of the United Provinces. But for this grant it would have been impossible to buy the necessary apparatus. Our thanks are also due to Mr. R. R. Bajpai for his kind help in taking observations.

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OSCULATING QUADRICS OF A RULED SURFACE

BY R. BEHARI

MATHEMATICS DEPARTMENT, UNIVERSITY OF DELHI

Received November 29, 1938

SUMMARY

The object of this paper is to obtain analytically the condition that the osculating quadrics of a ruled surface be equilateral (*i.e.*, have three mutually perpendicular generators) and to obtain some theorems on ruled surfaces which touch a given ruled surface along a generator.

1. Let the equations of a ruled surface be $x=p+lu$, $y=q+mu$, $z=r+nu$, where $p, q, r; l, m, n$ are functions of v , the arc of the base curve.

The differential equation of the curved asymptotic lines of the ruled surface is

$$\begin{aligned}\frac{du}{dv} &= -(\lambda + \mu u + \nu u^2)/2\delta, \text{ where} \\ \lambda &= \Sigma l (q' r'' - r' q''), \\ \mu &= \Sigma l \{ (m' r'' - m'' r') + (q' n'' - n' q'') \}, \\ \nu &= \Sigma l (m' n'' - n' m''), \\ \delta &= \Sigma l (q' n' - r' m'),\end{aligned}$$

the accents indicating differentiation with respect to v ; or

$$\frac{du}{dv} = \alpha + \beta u + \gamma u^2, \text{ where } \alpha = -\frac{\lambda}{2\delta}, \beta = -\frac{\mu}{2\delta}, \gamma = -\frac{\nu}{2\delta}.$$

It is assumed that $\delta \neq 0$ so that the ruled surface is non-developable.

The object of this paper is to obtain analytically the condition that the osculating quadrics of a ruled surface be equilateral (*i.e.*, have three mutually perpendicular generators) and to obtain some theorems on ruled surfaces which touch a given ruled surface along a generator.

2. The tangent to the asymptotic line at the point (u, v) is given by

$$\frac{x-p-lu}{p'+l'u+(\alpha+\beta u+\gamma u^2)l} = \frac{y-q-mu}{q'+m'u+(\alpha+\beta u+\gamma u^2)m} = \frac{z-r-nu}{r'+n'u+(\alpha+\beta u+\gamma u^2)n} \dots (1)$$

When u varies, the point (u, v) describes a generator, and the tangents form a quadric. Also since the generator and the tangent to the asymptotic are two distinct lines that touch both the quadric and the ruled surface it follows that:—

*The quadric generated by the tangents to the curved asymptotic lines at their points of intersection with a generator touches the ruled surface all along that generator.*²

3. Condition that the Osculating Quadrics of a Ruled Surface be equilateral.

Take an orthogonal trajectory of the generators for the base curve, so that $\Sigma lp' = 0$.

Let ξ, η, ζ be the direction cosines of a generator of the director cone of the osculating quadric, then we have

$$\frac{u^2 \gamma l + u(l' + \beta l) + (p' + \alpha l)}{\xi} = \frac{u^2 \gamma m + u(m' + \beta m) + (q' + \alpha m)}{\eta}$$

$$= \frac{u^2 \gamma n + u(n' + \beta n) + (r' + \alpha n)}{\zeta} \equiv \frac{Au + B}{\Sigma l' \xi} \equiv \frac{Bu + 1}{\Sigma p' \xi} \equiv \frac{u^2 \gamma + u\beta + \alpha}{\Sigma l \xi} = k,$$

say, where $A \equiv \Sigma l'^2$ and $B \equiv \Sigma l' p'$.

$$\therefore uA - k \Sigma l' \xi = -B \dots \dots \dots (a)$$

$$uB - k \Sigma p' \xi = -1 \dots \dots \dots (b)$$

$$u^2 \gamma + u\beta - k \Sigma l \xi + \alpha = 0 \dots \dots (c)$$

From (a) and (b) we get

$$u = \frac{-B \Sigma p' \xi + \Sigma l' \xi}{A \Sigma p' \xi - B \Sigma l' \xi},$$

$$k = \frac{-B^2 + A}{A \Sigma p' \xi - B \Sigma l' \xi}.$$

Putting these values of u and k in (c) we get $\gamma(-B \Sigma p' \xi + \Sigma l' \xi)^2 + \beta(-B \Sigma p' \xi + \Sigma l' \xi)(A \Sigma p' \xi - B \Sigma l' \xi) - \Sigma l \xi \cdot (A - B^2)(A \Sigma p' \xi - B \Sigma l' \xi) + \alpha(A \Sigma p' \xi - B \Sigma l' \xi)^2 = 0$.

The coefficient of ξ^2 on the left-hand side is $\gamma(-Bp' + l')^2 + \beta(-Bp' + l')(Ap' - Bl') + \alpha(Ap' - Bl')^2 - (A - B^2)(Ap' - Bl')$.

The osculating quadric is equilateral if the sum of the coefficients of ξ^2, η^2, ζ^2 is zero, i.e., if

$$\gamma(A - B^2) + \beta(B^2 - BA) + \alpha(A^2 - AB^2) = 0,$$

$$\text{i.e., } (A - B^2)(\gamma - \beta B + \alpha A) = 0,$$

and hence if either $A - B^2 = 0$, or $\gamma - \beta B + \alpha A = 0$.

But $A - B^2 \neq 0$, because if it were, the parameter of distribution would be zero, and the surface would be developable which is not the case.

$\therefore \gamma - \beta B + \alpha A = 0$ is the condition that the osculating quadric of the ruled surface be equilateral, when the base curve is an orthogonal trajectory of the generators.

This condition can also be obtained from purely geometrical considerations as follows.

The quadric osculating a ruled surface along a generator is equilateral if the two tangents to the curved asymptotics which are perpendicular to the generator lie in perpendicular planes through the generator, because then the generator and these two tangents are three mutually perpendicular generators of the osculating

hyperboloid. Now the points on the generator at which the curved asymptotics are perpendicular to the generator are given by the two values of u that satisfy $\alpha + \beta u + \gamma u^2 = 0$. These two values of u must belong to the involution formed by pairs of points along the generator the tangent planes at which are perpendicular and hence must be harmonic with respect to the roots of $1 + 2Bu + Au^2 = 0$, the condition for which is $\gamma - \beta B + \alpha A = 0$.¹

4. Equating each of the three ratios (1) in § 2 to $\frac{1}{\rho}$ we get $[\rho u + (\alpha + \beta u + \gamma u^2)]l + l'u - \rho(x - p) + p' = 0$ and two similar equations. Solving these three equations by means of determinants for $\rho u + (\alpha + \beta u + \gamma u^2)$, u and ρ we get $\rho u + (\alpha + \beta u + \gamma u^2) = \frac{P}{Q}$, $u = \frac{R}{Q}$, $\rho = \frac{K}{Q}$,

where P , Q , R are linear functions of $x - p$, $y - q$, $z - r$, and K is a constant (i.e., a function of r).

\therefore eliminating u we get the quadric

$$R(K + \gamma R) + Q(\beta R + \alpha Q - P) = 0. \dots (2)$$

This result is true whatever values we give to the constants α , β , γ . The case of the curved asymptotics gives one quadric, but for other values of α , β , γ we get an ∞^3 of quadrics all of which touch the given ruled surface along the generator. The contact is of the second order only for the osculating quadric. In order that the osculating quadrics be equilateral, we have to choose α , β , γ satisfying $\gamma - \beta B + \alpha A = 0$. Hence it follows that:—

Out of these ∞^3 quadrics, ∞^2 are equilateral.

The osculating quadric (2) becomes a paraboloid when and only when $\gamma = 0$, i.e., when the generators of the ruled surface are parallel to a plane. The conoid is a special case.

5. Since the differential equation of the curved asymptotic lines is $\frac{du}{dv} = \alpha + \beta u + \gamma u^2$, the differential equation of the orthogonal trajectories of the curved asymptotic lines is of the form

$$\frac{du}{dv} = \frac{a + bu + cu^2}{a' + b'u + c'u^2}.$$

Using $\frac{a + bu + cu^2}{a' + b'u + c'u^2}$ instead of $\alpha + \beta u + \gamma u^2$ and performing the elimination as in § 4, we get

$$\frac{KR}{Q^2} + \frac{aQ^2 + bQR + cR^2}{a'Q^2 + b'QR + c'R^2} = \frac{P}{Q},$$

from which we deduce the following theorem:—

If at points along a generator of a ruled surface, tangent lines are drawn to the orthogonal trajectories of the curved asymptotic lines, then these lines generate a Quartic Ruled Surface touching the given ruled surface.

The quartic reduces to a cubic if $\gamma=0$, i.e., whenever the generators are parallel to a plane. (The right helicoid is excluded from this theorem, since it is a minimal surface.)

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ON THE TREMATODE GENUS *LYPEROSOMUM* LOOSS, 1899
(DICROCOELIIDAE) WITH A DESCRIPTION OF
TWO NEW SPECIES FROM INDIA

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SUMMARY

Two new species of trematodes belonging to the genus *Lyperosomum* have been described in this paper; some remarks on the genus have also been given.

Lyperosomum Looss, 1899.

Looss (1899) proposed this generic name, without naming a type species, for the following species of *Dicrocoelium*, *D. porrectum* (Braun), *D. plesiostomum* (V. Linstow), *D. longicauda* (Rud.), *D. clathratum* (Deslongchamps), and *D. stronglylosum* Looss. All these species were removed from *Dicrocoelium* because of their elongated bodies with pointed extremities, nearly rounded in cross-section, and testes situated one behind the other. Braun (1901) added three more species to this genus as new, *corrigia*, *rudectum*, and *salebrosum*. A year later, Braun (1902) dealt with and figured the following species under *Lyperosomum*: *porrectum*, *longicauda*, *corrigia*, *rudectum* and *salebrosum*, making *longicauda* as the type of this genus. In the same paper a figure of *Lyperosomum* sp. (V. Linstow) was also given without any description. In 1906 Van Linstow described *L. squamatum*. Looss (1907), while expressing his views on the relationships of the known members of the Dicrocoeliinae, included in this genus *L. longicauda*, *L. olssoni* (Railliet) (*Dist. clathratum* Olsson and Muhling, after Deslongchamps), *L. lobatum* (Railliet), *L. strigosum*, *L. corrigia*, *L. rudectum*, and *L. salebrosum*. In the same paper, *D. clathratum* Deslongchamps (*D. refertum* Muhling of Railliet) was removed to his new genus *Platynosomum* which he characterised by a much broader body with symmetrically placed testes to the right and left sides of the acetabulum close behind it. Thus an addition of two more species, *lobatum* and *olssoni*, was made by Looss. Skrjabin (1913) proved that *L. squamatum* did not belong to this genus and recognising the nine species, *longicauda*, *lobatum*, *porrectum*, *corrigia*, *olssoni*, *salebrosum*, *strigosum*, *rudectum*, *plesiostomum*, described a new species under the name of *L. filliforme*. Nicoll (1914) described two more species, *L. scitulum* and *L. direptum*. Johnston (1916) gave an account of three more species

of this genus designating them as *L. parvum*, *L. megastomum*, and *L. harrisoni*. Five more species were added to the genus by Travassos (1917), viz., *L. obliquum*, *L. transversum*, *L. rarum*, *L. lavi*, and *L. sinuosum*. Travassos (1919) removed Nicoll's *direptum* to his new genus *Oswaldoia*, which is characterised by a broader body and obliquely situated testes, and has recently been studied by Strom (1928) and Skrzabin and Udinzew (1930). Another species, *L. donicum* was described by Isaitschikoff (1917) who also showed that *Dicrocoelium attenuatum* belongs to *Lyperosomum*. Layman (1922) added three more new species and a new sub-species under the name of *L. magnitesticum*, *L. vanellicola*, *L. transversogenitalis*, and *L. transverso-genitalis turkestanicum*. Layman made further additions to our knowledge of the members of this genus. In 1923 he added *L. fringillae* and in 1926 *L. lanicola*, *L. usowi*, *L. loossi*, *L. alaudae*, and *L. transverso-genitalis donicum*. Bhalerao (1926) described another new species as *L. kakea*. Baylis (1927) has shown that *Dicrocoelium vitta* of Dujardin should be classified as *L. vitta*. Semenow (1927) has described three sub-species *L. transverso-genitalis sylvestris*, *L. filliforme biologica*, and *L. lobatum glandarii*. Skrzabin and Udinzew (1930) have described another species of *Lyperosomum*, *L. papabejani*, and given a very useful key for the identification of the known species of this genus. Since then Yamaguti (1933), Patwardhan (1935), and Price and McIntosh (1935) have studied members of this genus.

Yamaguti has described *L. attenuatum* and a new species, *L. microscelis*, and also pointed out that *D. clathratum* Desl. of Muhling should be transferred to *Lyperosomum* from *Platynosomum*; Patwardhan has given an account of another new species, *L. colorosum*; and Price and McIntosh describe a remarkable new species as *L. monenteron*.

Of the numerous species that have so far been assigned to this genus, as will appear from the list given above, fifteen species and five sub-species alone are from Russia. To the two species of *Lyperosomum*, *L. kakea* and *L. colorosum*, hitherto known from this country, the author adds two new species in the present paper.

Lyperosomum stunkardi sp.n. (Figs. 1 and 2)

Host: *Garrulus lanceolatus*, bile ducts.

Locality: Almora, Kumaon Hills.

Description.—Body elongated, filamentous, cylindrical, uniformly broad, 5.8-6.6 in length and 0.21-0.27 in breadth.* Numerous well-developed unicellular glands with prominent nuclei in the body parenchyma. Oral sucker subterminal, spherical, 0.2-0.25 in diameter; pharynx longer than broad, 0.06-0.08 × 0.05-0.07 in size; oesophagus 0.15 in length; oesophageal bifurcation a little posterior to the

* All measurements are in millimetres.

middle of the pre-acetabular part of the body; posterior extent of the intestinal caeca difficult to trace on account of numerous eggs. Acetabulum with a pair of

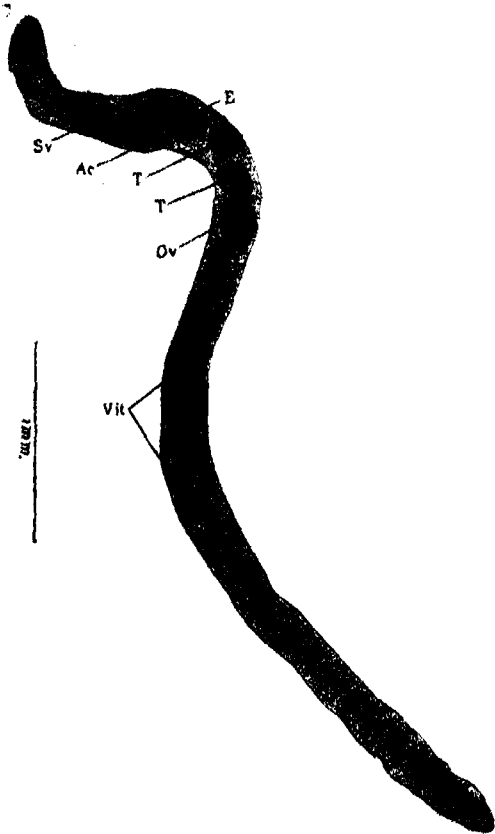


Fig. 1

Lyperosomum stunkardi sp. n.

Entire worm.

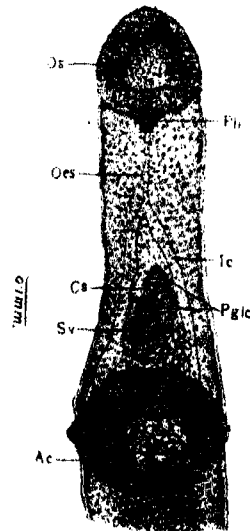


Fig. 2

Anterior region of *L. stunkardi*
showing ear-shaped appendages
on the acetabulum.

Ac, acetabulum; *C*, cirrus; *cs*, cirrus sac; *E*, egg; *Ic*, intestinal caecum; *Oes*, oesophagus; *Os*, oral sucker; *Ov*, ovary; *Pgle*, prostate gland cells; *Ph*, pharynx; *Sr*, seminal receptacle; *Sv*, seminal vesicle; *T*, testis; *Ut*, uterus; *Vit*, vitelline follicles; *Yr*, yolk-reservoir.

ear-shaped appendages, broader than long, $0.27-0.3 \times 0.32-0.35$ in size, situated between one-seventh and one-eighth of body length from the anterior extremity. Excretory system same as in the following species. Genital pore median, some distance behind the intestinal bifurcation. Testes nearly spherical and equal in size, slightly diagonally situated, one close behind the other, with a coil of the uterus

between them, separated from the acetabulum by a few coils of the uterus, and measuring 0.16×0.17 in size; cirrus-sac $0.18-0.21$ in length and $0.1-0.11$ in breadth, with its nearly two-thirds of the length occupied by the coiled vesicula seminalis, entirely in front of the acetabulum, and with the prostate gland cells in the space between the wall of the cirrus-sac and vesicula seminalis, small pars prostatica and ductus ejaculatorius. Ovary globular only slightly larger than the testes, 0.18 in diameter, situated close behind the posterior testis with a uterine coil between them; shell-gland mass immediately posterior to the ovary, lateral in position; receptaculum seminis was not observed; Laurer's canal present; vitellaria consisting of about fourteen large follicles on each side, commence immediately posterior to the shell-gland mass, covering a lateral field of about $1.1-1.2$ length; post-vitelline space $1.86-2.2$ in length; uterus extensively developed, containing numerous eggs, occupying the entire space behind vitellaria, between vitelline follicles and intestinal caeca in the vitelline region, in front of shell-gland mass the ascending uterus coiling around testes and passing to the genital pore lying between anterior testes and acetabulum and dorsal to the latter; ripe eggs measure 0.035 in length and 0.0245 in breadth.

Remarks:—The two hitherto known species of *Lyperosomum* from India, *L. kakea* and *L. colorosum*, differ from the proposed new species, *L. stunkardi*, in their smaller length and rounded acetabulum without ear-shaped appendages. *L. kakea* is further distinguished by the position of its genital pore situated some distance behind the pharynx, oval shape of its testes, ovoid ovary lying with its longer axis transverse to the body length, and smaller breadth of its eggs. *L. colorosum*, unlike the present species, is characterised by the position of the genital pore midway between the anterior end of the body and the rim of the acetabulum, and the ovary smaller in size than the testes.

The position of the vitellaria commencing behind the ovary distinguishes *L. stunkardi* sp.n. from *longicauda*, *lari*, *corrigia*, *plesiostomum*, *obliquum*, *scitulum*, and *papabejani*. The relative size of the ovary and the testes separates the present form from all the other species of *Lyperosomum* except *L. fringillae*, *strigosum*, *filliforme*, *filliforme biologica* and *lobatum glandarii* which have the ovary larger than the testes. *L. fringillae* differs from the new species in its smaller body size, transversely oval genital glands, and much greater length of its eggs. *L. strigosum* is distinguished from the new species on account of its smaller body size, absence of ear-shaped appendages on the acetabulum, transversely elongated testes, posterior extent of the cirrus-sac, and greater length of the eggs. *L. filliforme* is distinguished from the new species by the absence of ear-shaped appendages on the acetabulum, longitudinally elongated oval testes, and greater length of its eggs. *L. lobatum glandarii* is separated from *stunkardi* sp.n. on account of the shape of the ovary which is triangular and rounded, and longitudinally oval testes. *L. filliforme biologica*

is distinguished from the new species by the smaller size of the body, transversely oval ovary, different shapes of the testes—one rounded and the other oval, and greater length of its eggs.

Lyperosomum bhattacharyai sp.n. (Fig. 3)

Host: *Sturnopastor capensis* and *Temenuchus pagodarum*, gall bladder and bile ducts.

Locality: Allahabad.

Description:—body slender, elongated, nearly cylindrical, tapering towards ends, with somewhat rounded anterior and pointed posterior extremities; narrower pre-acetabular part provided with a dorsal preoral lip. Length 3·8; breadth more or

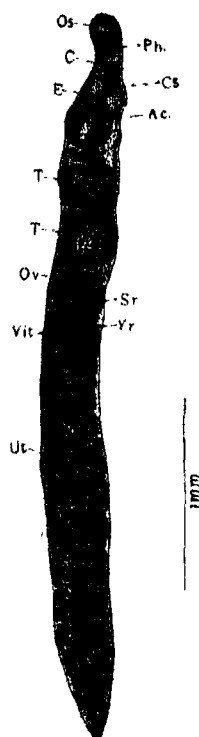


Fig. 3

L. bhattacharyai sp. n., Entire worm.

Lettering as in Figs. 1 and 2.

less uniform in the acetabular and post-acetabular parts of the body, 0·3 in acetabular and testicular zones and 0·34 in uterine zone. A large number of unicellular cutaneous glands present in the body parenchyma with prominent nuclei. Oral sucker sub-terminal, 0·12 × 0·14 in size; pharynx broader than long, 0·05 × 0·07 in size; oesophagus

short, about 0.08 in length; posterior extent of intestinal caeca difficult to trace on account of the large number of eggs in the uterus. Acetabulum longer than broad, 0.27×0.25 in size, situated at about 0.55 distance from anterior end of the body, i.e., at nearly one-seventh of the body length from the anterior extremity. Excretory pore at the posterior end. Excretory bladder long, tubular, reaching anteriorly near the middle of the vitelline area and receiving a pair of short common collecting tubes antero-laterally; common collecting tubes passing diagonally outwards receive anterior and posterior collecting branches at about the middle of the ovary. Genital pore behind intestinal bifurcation, 0.28 distance from the anterior end of the ovary. Testes nearly spherical, situated slightly diagonally one behind the other with uterine coils separating them; anterior testis 0.23×0.25 in size, separated from the acetabulum by coils of the uterus; posterior testis slightly larger than the former, 0.25×0.27 in size; cirrus-sac oval in shape, 0.1 in length and 0.06 in breadth, in front of the acetabulum, with a coiled vesicula seminalis occupying its greater part and continuing into small pars prostatica and well-developed ductus ejaculatorius; cirrus, when everted, measuring 0.09×0.04 in size. Ovary smaller in size than the testes, broader than long, 0.16×0.2 in size, separated from the posterior testis by the uterine loop, in line with the anterior testis; receptaculum seminis median, circular in outline, 0.08 in diameter, overlapping the ovary on its posterior border; shell-gland mass close behind the receptaculum seminis; vitellaria symmetrical, composed of eleven follicles in two lateral rows one on each side, situated at the middle of body length, limited to an area of 0.5 length, with the anterior follicles in the region of the receptaculum seminis and shell-gland mass; uterus intricately coiled and containing numerous eggs, filling up all the space not occupied by other organs behind the shell-gland mass, and in front of the latter the ascending limb of the uterus coiling around the ovary and testes passes to the genital pore lying dorsal to the acetabulum; ripe eggs deep brown in colour, 0.0315×0.021 in size.

Remarks :—Of the three Indian species of *Lyperosomum* *L. kakea*, *L. colorosum*, and *L. stunkardi* sp. n., the proposed new species, *L. bhattacharyai* stands closer to *colorosum* on account of the equal size of the body, similar sucker ratio, absence of ear-shaped appendages on the acetabulum, and ovary smaller than the testes. It, however, differs from *colorosum* in the more posterior position of the genital pore (in *colorosum* genital pore lies midway between the anterior end of the body and the anterior border of the acetabulum) and more anterior position of the vitellaria composed of a larger number of follicles (follicles numbering 6-7 in *colorosum* commence behind the middle of body length) besides other differences such as the shape of the ovary which is spherical in *colorosum*. Of the various species that have been described under this genus up to the present moment excluding the Indian representatives, the present species on account of the vitellaria commencing behind the ovary, testes being larger in size than the ovary and situated one behind

the other very near to the acetabulum, uterine coils separating the anterior testis from the acetabulum and without partial overlapping of the genital glands, agrees with the three sub-species of *transversogenitalis*, *attenuatum*, *parvum*, and *harrisoni*. *L. bhattacharyai* sp. n. is distinguished from *transversogenitalis donicum*, *transversogenitalis turkestanicum*, and *transversogenitalis sylvestris* by the size of the body, shape of the testes, and disposition of the vitelline follicles. It differs from *L. attenuatum* (after Yamaguti), in the ovary being broader than long (rounded in *attenuatum*), more anterior position of the acetabulum (acetabulum rounded in *attenuatum* and lies at one-sixth of body length from the anterior end), and more posterior extent of the cirrus-sac (in *attenuatum* cirrus-sac lies approximately halfway between suckers). *L. parvum* is separated from the new species on account of the sucker ratio (oral sucker 0.213×0.194 and acetabulum 0.252×0.233 in *parvum*), much posterior position of the cirrus-sac in relation to the acetabulum (lying mainly dorsal to it in *parvum*), cubical form of the testes, and larger size of its eggs (average 0.039×0.023 in *parvum*). *L. harrisoni* differs from *L. bhattacharyai* sp. n. in the sucker ratio (oral sucker 0.223 and acetabulum 0.262 in diameter), testes being broader than long, cirrus-sac does not lie wholly in front of acetabulum, and larger size of the eggs (0.038×0.024 in *harrisoni*).

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TWO NEW SPECIES OF TREMATODES FROM *ANHINGA*
MELANOGASTER, THE INDIAN DARTER OR
SNAKE-BIRD

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SUMMARY

Two new species of trematodes obtained from the intestine of an Indian darter or snake-bird, *Anhinga melanogaster*, have been described in this paper.

The two species of trematodes herein described were obtained from the intestine of an Indian Darter or Snake-bird, *Anhinga melanogaster*, one of which represents a new species of the genus *Petasiger* Dietz (Family Echinostomatidæ) and the other is a third representative from India of the genus *Apatemon* Szidat (Family Strigeidæ).

Family : Echinostomatidae Poche, 1926.

Subfamily : Echinostominae Looss, 1899.

Genus *Petasiger* Dietz, 1909.

This genus was proposed by Dietz in 1909 with *Petasiger exaeretus* Dietz (1909) as the type species. A year later, Dietz gave a generic diagnosis of *Petasiger* followed by an account of *P. exaeretus*. Odhner (1911) included under this genus his *Echinostomum variospinosum* described in the same paper, and observed that *Ech. pungens* V. Linstow and *Ech. magniovatum* Stossich show relationship to this genus and should be included under it. Kotlan (1922) gave an account of *P. exaeretus* and described a new species under the name of *Echinostomum megacanthum*. Regarding the systematic position of *megacanthum*, which is undoubtedly a member of this genus, Kotlan observed that the species probably was the representative of a special genus though its form and internal organisation was near to *Petasiger*. Very likely this author was led to take this view on the number and arrangement of collar spines. In regard to the species, *pungens* and *magniovatum* which appeared to Kotlan as the species nearest to his *megacanthum*, whether they should be included under *Petasiger*, Kotlan left the question undecided. Subsequently up to this date the new species that have been added to this genus are : *nitidus* (Linton, 1928), *neocomense*

(Fuhrmann, 1928), *novemdecim* (Lutz, 1928), *lobatus* (Yamaguti, 1933), *minutissimus* (Gogate, 1934), and *grandiresicularis* (Ishii, 1935). Davis (1934) has given a detailed account of the type species of this genus.

The first and the only record so far of a species belonging to this genus from India is that by Gogate (1934) who has described a species from wild ducks in Rangoon under the name of *P. minutissimus*.

This genus, which is closely related to *Paryphostomum* Dietz (1909), was not assigned to any of the three subfamilies of Echinostomatidae by Odhner (1911). The remarkable difference between these two genera lies in the character of their testes according to the diagnoses given by Dietz (1910). The testes are transversely elongated with entire margins in *Petasiger* and deeply lobed in *Paryphostomum*. The latter genus has been allocated to the subfamily Himasthlinae Odhner (1911) by Bhalarao (1931). But it appears doubtful whether *Paryphostomum* should be included under the latter subfamily. In the present paper *Petasiger* is provisionally assigned to the subfamily Echinostominae.

Petasiger nicolli n. sp. (Figs. 1 and 2)

Description.—Body elongated, somewhat spindle-shaped, flattened dorso-ventrally, with broader anterior extremity and pointed posterior end, and 2.93* in length and 0.73 in maximum breadth in the region of the acetabulum. Cuticle spinose; spines thickly set in pre-acetabular part of body, measuring 0.028 in length and 0.007 in basal width. At the anterior end body widened to form a well-developed collar, not united ventrally, 0.17 in length and 0.5 in breadth, bearing 27 spines uninterrupted dorsally; four collar-spines on each side forming ventral end group and larger than others, 0.1 in length and 0.04 in basal width; remaining nineteen spines arranged in two alternating rows and forming the dorsal and marginal spines, 0.07–0.08 in length and 0.02 in basal width. Oral sucker small, nearly globular or slightly broader than long, nearly terminal, 0.14 × 0.15 in size; prepharynx not observed; pharynx slightly smaller than oral sucker, 0.13 in diameter; oesophagus 0.34 in length, surrounded by a dense mass of well-developed unicellular glands, bifurcating into intestinal caeca a little in front of anterior fourth of body; intestinal caeca, as also oesophagus, in the living condition appearing dull red on account of contained blood of the host, terminating a little in front of the hinder body extremity. Acetabulum well-developed and muscular, 0.44 × 0.37 in size, situated immediately posterior to one-third of body length from anterior end. Excretory pore terminal; excretory bladder Y-shaped. Separate genital pores for male and female terminal ducts, situated medianly close behind intestinal bifurcation. Testes oval, situated obliquely one behind the other in the hinder half of the third quarter

* All measurements are in mm.

of the body ; anterior testis sinistral, 0'22 in length and 0'27 in breadth ; posterior testis nearly median, 0'22 in length and 0'3 in breadth. Cirrus-sac elongated, median, parallel to body length, extending posteriorly to some distance behind anterior border of acetabulum, anteriorly slightly ventrally inclined ; voluminous vesicula seminalis occupying greater part of cirrus-sac ; small pars prostatica and

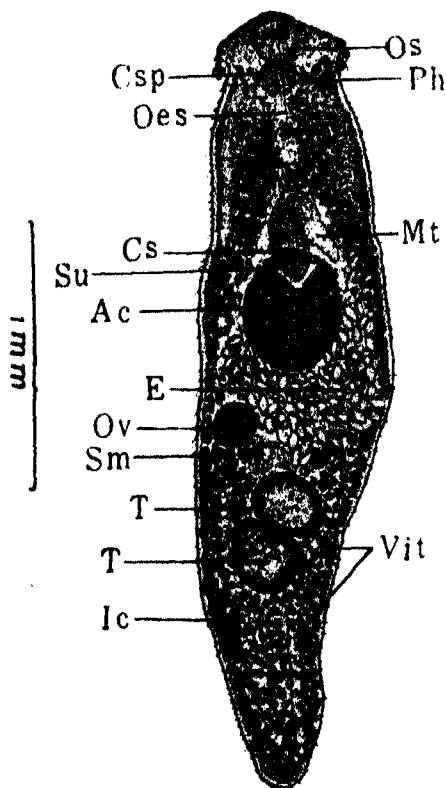


Fig. 1

Petasiger nicolli n. sp. Entire specimen.

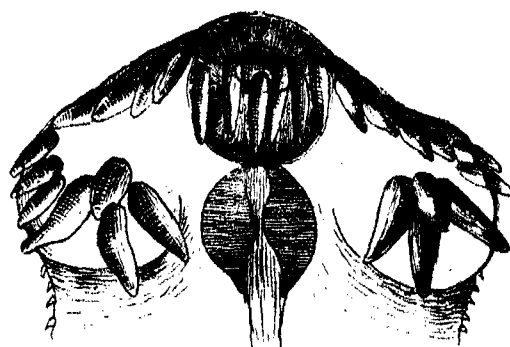


Fig. 2

Collar-spines of *P. nicolli* n. sp.

Ao. acetabulum ; *Os*, cirrus-sac ; *Csp.* collar spine ; *E*, egg ; *Ga*, genital atrium ; *Gc*, genital cone ; *Gp*, genital pore ; *Ic*, intestinal caecum ; *Mt*, metraterm ; *Oes*, oesophagus ; *Os*, oral sucker ; *Ov*, ovary ; *Ph*, pharynx ; *Sm*, shell-gland mass ; *Sv*, seminal vesicle ; *T*, testis ; *Vit*, vitelline follicles ; *Yr*, yolk-reservoir.

ductus ejaculatorius and comparatively a few prostate gland cells in the small anterior part of the cirrus-sac. Ovary nearly rounded, situated close behind middle of body near body wall on the right side, 0'16 in length and 0'17 in breadth ; shell-gland mass internal to ovary between it and anterior testis ; receptaculum seminis absent ; uterus full of large number of eggs in the space between anterior testis and

acetabulum, terminating in a well-developed metraterm of nearly the same size as the cirrus-sac; vitellaria occupying mostly lateral margins of body from the level of the genital pores to near the hinder body extremity, follicles uniting in median line in post-testicular region of body; ripe eggs of 0.08 length and 0.052 breadth.

Remarks.—The number of spines in the collar separates *P. nicolli* n. sp. from *pungens*, *magniovatum*, *megacanthum*, *nitidus*, *novemdecim*, *minutissimus* and *grandi-vesicularis*. Of these seven species, *magniovatum*, *megacanthum*, *nitidus*, *novemdecim* and *grandi-vesicularis* are characterised by the collar bearing only nineteen spines. In *pungens* Odhner gives the number of spines as twenty-one but according to Kotlan their number varies from nineteen to twenty-one. *P. minutissimus* has twenty-three spines on its collar, three of which on each side constitute end groups. *P. lobatus* (Yamaguti), possessing nineteen collar-spines, is removed from *Pelasiger* on account of its lobate testes and transferred to *Paryphostomum*.

The new species on account of the collar-spines numbering twenty seven resembles *P. exaeretus*, *P. variospinosum* and *P. neocomense*. *P. neocomense* is distinguished from *P. nicolli* n. sp. by its collar spines arranged in one row. *P. exaeretus* and *P. variospinosum* stand closer to the new species on account of the arrangement of the collar-spines in two rows. *P. nicolli* n. sp. is sharply separated off from *exaeretus* on account of its larger body size, absence of a prepharynx, presence of a dense mass of unicellular glands around oesophagus, oblique position of the testes, absence of a receptaculum seminis, more anterior extent of vitellaria (beginning opposite the anterior border of acetabulum in *exaeretus*), uterus with a larger number of eggs, and different size of the eggs. It is distinguished from *P. variospinosum* by the greater size of its body, different sucker ratio, larger size of its testes, smaller size of pars prostatica, few prostate gland cells, much larger number of eggs in the uterus, and different sizes of its eggs.

Family: Strigeidae Railliet.

Subfamily: Strigeinae Railliet.

Sub-subfamily: Cotylurini Dubois, 1936.

Genus: *Apatemon* Szidat, 1929.

Szidat (1929) created this genus for the strigeid trematodes characterised by cup-shaped and widely open fore-body containing a well-developed holdfast organ, cylindrical and dorsally flexed hind-body, vitellaria exclusively confined to the hind-body, and absence of a well-developed and clearly defined genital atrium. He assigned three species to this genus: *A. gracilis* (Rudolphi, 1819), *A. sphaerocephalus* (Brandes, 1888), and *A. graciliformis* Szidat (1929). Since then a large number of species have been added to this genus, viz., *A. fuligulae*, *A. pellucidus* and *A. minor* by Yamaguti (1933), *A. classocotylus* by Dubois (1934), *A. japonicus* by Ishii (1934), *A. parvitesis* by Ishii (1935), and *A. indicus* and

A. casarcus by Vidyarthi (1937). The last two species have been reported from India. Following Dubois (1936), the genus *Apatemon* is assigned to his sub-sub-family Cotylurini under the family Strigeidae.

Apatemon pandubi n. sp. (Figs. 3 and 4)

Description.—Body divided into a cup-shaped fore-body and a cylindrical hind-body; strongly flexed at the junction of the two regions. Fore-body nearly spherical, 0.5-0.7 in length and 0.55-0.6 in breadth; hind-body nearly one and a half time longer than the fore-body, 0.85-1.3 in length and 0.65 in maximum breadth in the region of the testes. Oral sucker terminal, 0.12-0.14 × 0.1-0.12 in size; prepharynx absent; pharynx oval in shape, 0.07 in length and 0.05 in breadth; oesophagus very short, 0.017 in length, dividing

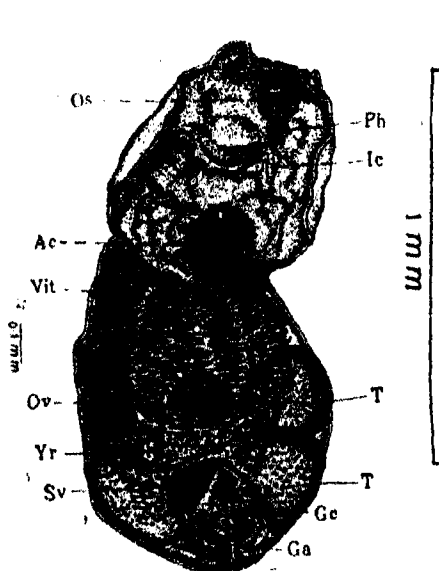


Fig. 3

Apatemon pandubi n. sp., dorsally flattened specimen.

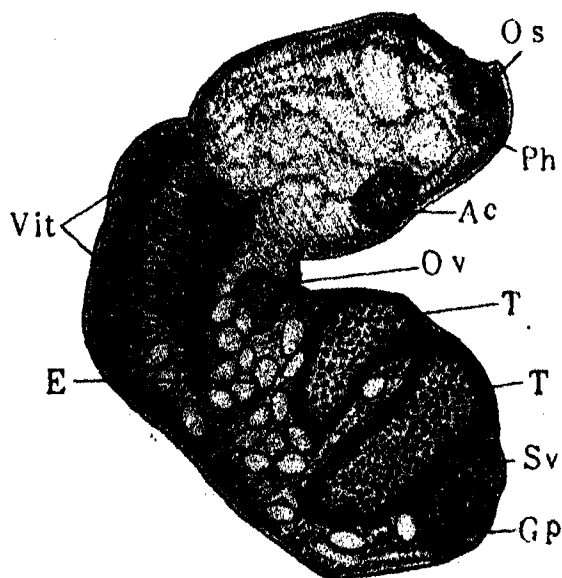


Fig. 4

A. pandubi, laterally flattened specimen.

Lettering same as in Figs. 1 and 2

into the intestinal caeca much in front of the acetabulum; intestinal caeca terminating near the posterior end of the body. Acetabulum larger than the oral sucker, 0.17-0.2 in length and 0.15 in breadth, situated dorsally in front of the body constriction. Hold-fast organ beginning at the hinder end of the fore-body, consisting of an outer and inner lobe, often protruding from the opening of the

fore-body; adhesive gland just beneath the hold-fast organ. Genital pore at the posterior end of the body, leading into a shallow funnel-shaped genital atrium. Testes situated nearer the posterior extremity of the body, lie close behind one other, immediately beneath the dorsal body wall; anterior testis asymmetrical, 0.24 in length and 0.23 in breadth (in the dorsoventrally flattened specimen), lateral in position; posterior testis nearly symmetrically bilobed with lobes connected anteriorly by a narrow isthmus, occupying the entire width of the body, each lobe nearly equal in size, 0.3 in length and 0.2 in breadth (in the dorsoventrally flattened specimen); vesicula seminalis very voluminous, coiled, lying in the testicular region ventrally to the testicular lobes and between the two limbs of the posterior testis, running distally into the small pars prostatica followed by the ejaculatory duct, both traversing the thick connective tissue of the genital cone, and opening with the terminal part of the uterus into the genital atrium. Ovary somewhat pear-shaped, 0.11-0.13 \times 0.15-0.17 in size, median in position, situated at the middle of the hind-body on the anterior testis (inside view appearing close in front of the anterior testis); shell-gland mass and well-developed yolk-reservoir nearly median, lying immediately in front of the posterior testis; uterus after its origin from the shell-gland mass first running forwards to the anterior end of the ovary then continuing as the descending limb to the posterior end of the body—coils lying ventral to the ovary, anterior testis and vesicula seminalis opening into the genital atrium ventrally to the opening of the ejaculatory duct; ripe eggs 0.0875 in length and 0.0595 in breadth; vitellaria occupying all the available space in the hind-body from the body constriction to near the middle of the posterior testis.

Remarks :—*Apatemon pandubi* n. sp. is distinguished from all the hitherto described species of the genus on account of the peculiar form of its posterior testis. The present species, however, resembles *A. casarcus* in the bilobed character of its posterior testis but differs from that species in the ratio in length of the fore and hind-body (1 : 2 in *casarcus*), more posterior position of the gonads (occupying the middle of the body in *casarcus*), unlobed nature of the anterior testis, presence of a small ejaculatory pouch, and greater development of the genital cone.

The author expresses his gratefulness to Dr. H. R. Mehra for his guidance and helpful criticisms.

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[Volume 9

THE THEORY OF A NEW RELATIVITY, CHAPTER XVI (GENERALISED GRAVITATION)

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SECTION I

INTRODUCTION

There are four and only four observational results in which the General Theory of Relativity differs from Newtonian Mechanics and these are (1) the advance of the perihelion of a planet, (2) the deflection of light from stars past the Sun, (3) the spectral shift of light from the Sun or a Star, and (4) the expansion of the Universe due to an extra cosmic force of repulsion increasing with the distance. And these are due, among other postulates, to the fundamental postulate of the absoluteness of the finite velocity of light. No matter how-soever fast another body may be moving and whether light be approaching it from the front or overtaking it from behind, the velocity of light though finite and equal to 3×10^{10} km/sec is relative to it always the same; and this will still be so even if the other body be an electron travelling with $\frac{9}{10}$ th of the velocity of light! In the Galactic rotation, the Sun and another star may be moving in the same curvilinear direction with a velocity about 300 km/sec, and yet the time taken by light to go from the Sun to the star will be exactly equal to the time taken by light to come from the star to the Sun! In all the text-books on Relativity the justification for these astounding postulates is based on the claim that the results of relativity as regards the first three matters, if not also the fourth, have been verified by observations. It would be quite sufficient to quote Einstein's own admission "If a single one of the conclusions drawn from it (Relativity) proves

wrong, it must be given up; to modify it without destroying the whole structure seems to be impossible."

The latest observations show large discrepancies in all except the first result. Leaving aside critics who never seem to agree and considering the conclusions of the observers themselves, Freundlich has found an excess of 25% in the deflection of light, Royds has found an excess of 100% in the spectral shift of light from the edge of the Sun and Hubble from nebular counts has shown that there is no expansion of the Universe at all. In any case no one can now assert that the recession of the nebulae is established.

Of course, prejudices in favour of an old theory continue long, and so in spite of the above discrepancies all that the author of the latest book on Relativity can concede is that it is as unwise to declare the relativity theory true and definitive as it is to declare it false and indefinite.

The General Theory has so far attempted the solution of one-centre problem only. "The problem of two bodies on Einstein's theory remains an outstanding challenge to mathematicians—like the problem of three bodies on Newton's theory." (Eddington.) The three bodies problem in Newtonian Mechanics has been at least partially solved by Sundman by means of series. But in Relativity the motion of the Moon has been deduced by "treating the mass of the Moon (which is one-eightieth of that of the Earth) as infinitesimal" (*Eddington's Relativity*, p. 97), and the theory breaks down when masses are comparable. This utter failure of Relativity is due to the impossibility of superposing the fields of force due to two attracting particles, because the sum of the two solutions will not satisfy $G_{\mu\nu} = 0$, these equations being non-linear in the $G_{\mu\nu}$. Relativity has, therefore, come to a deadlock. But the New Theory, proceeding strictly on Newtonian principles, gives results tallying with all the four latest observations, and presents no difficulty in the solution of Two Bodies or even Three Bodies problem. And what is more it identifies Electricity, Light and Gravitation completely.

Further observations will settle whether Relativity really represents the highest truth revealed to mankind or whether it is the grossest falsehood ever promulgated. It is to be sincerely hoped that to test the fundamental postulate of Relativity,

(1) the Michelson and Morley experiment will, as suggested by me in the last chapter, be performed with solar light (instead of terrestrial light) in the morning and on a date when the Earth has the greatest velocity of approach towards the Sun or in the evening and on a date when it has the greatest velocity of recession in its orbital motion,

and (2) as suggested by F. H. C. Smith in *Nature* (July 2, 1938, p. 40) the speed of light received from approaching and receding stars would be measured.

I must express my gratitude to Dr. D. S. Kothari, M.Sc., Ph.D., Reader in Physics at the Delhi University, for the benefit of his valuable opinion on Sections

II and III, and Mr. O. A. Siddiqi, M.Sc., Lecturer in Mathematics at the Muslim University, Aligarh, for checking Section VII.

SECTION II

EDDINGTON'S SOLUTION OF EINSTEIN'S DIFFERENTIAL EQUATION

1. In the General Theory of Relativity, the equation obtained by Einstein for the motion of an infinitesimal planet is

$$\frac{d^2 u}{d\theta^2} + u = \frac{\mu}{h^2} + \frac{3\mu}{c^2} u^2.$$

Sir Arthur Eddington in his Relativity (§ 40, p. 88) has deduced its approximate solution in the following way :

Neglecting the small term $\frac{3\mu}{c^2} u^2$ the solution is

$$u = \frac{\mu}{h^2} \{1 + e \cos(\theta - \omega)\}$$

where e and ω are constants.

Substituting this first approximation in the small term of the differential equation, we get

$$\begin{aligned} \frac{d^2 u}{d\theta^2} &= \frac{\mu}{h^2} + \frac{3\mu^2}{c^2 h^4} + \frac{6\mu^3}{c^2 h^4} e \cos(\theta - \omega) \\ &+ \frac{3}{2} \frac{\mu^3 e^2}{c^2 h^4} \{1 + \cos 2(\theta - \omega)\} \end{aligned} \quad (51.1)$$

It is then suggested that "of the additional terms the only one which can produce an effect within the range of observation is the term in $\cos(\theta - \omega)$, this is of the right period to produce a continually increasing effect by resonance."

Neglecting $\frac{3\mu^3}{c^2 h^4} \left(1 + \frac{e^2}{2}\right)$ and the term containing $\cos 2(\theta - \omega)$ the solution is obtained as

$$\begin{aligned} u &= \frac{\mu}{h^2} \left\{ 1 + e \cos(\theta - \omega) + \frac{3\mu^2}{c^2 h^2} e \theta \sin(\theta - \omega) \right\} \\ &= \frac{\mu}{h^2} \left\{ 1 + e \cos(\theta - \omega - \epsilon) \right\} \\ &= \frac{\mu}{h^2} \left\{ 1 + e \cos(1 - 3k^2)\theta \right\} \end{aligned}$$

$$\text{where } \epsilon = \frac{3\mu^2}{c^2 h^2} \theta = 3k^2 \theta. \quad (51.2)$$

From this by integration the value of the advance of the perihelion for one revolution is obtained.

2 Taking the supposed solution as

$$u = \frac{\mu}{h} \left[1 + e \cos \{ (1 - 3k^2)\theta - \omega \} \right]$$

it is obviously the solution of

$$\frac{d^2 u}{d\{\{(1-3k^2)\theta - \omega\}^2} + u = \frac{\mu}{h^2}$$

$$\text{or } \frac{d^2 u}{d\theta^2} + u = \frac{\mu}{h^2} (1 - 6k^2) + 6k^2 u$$

$$\text{neglecting } k^4 \quad (51.3)$$

This differential equation is quite different from Einstein's equation as its last term contains u and not u^2 and its coefficient also is different

3 It has been shown by me (*Philosophical Magazine* Vol XXVI pp 983—87) that the neglect of the term containing $\cos 2(\theta - \omega)$ before solving the equation is erroneous on several grounds

For other consequences of the equation like (51.3) see the next section

4 M Jean Becquere in his *Le Principe De Relativite* Ch XIV, Sec 93, pp 231—4 at p 233 (19) has adopted exactly the same method of neglecting the second periodic term on the ground of want of resonance, and so the same objections apply to his method also

SECTION III

LEVI CIVITA'S FORMULAE FOR TWO BODIES

1 It was shown in *Pr Ac Sc India* 4 20—23 (August 1934) that extra terms, in the equation of motion as compared to Newton's, can be treated as being due to small perturbing forces and the changes in the elements of the orbit deduced by ordinary Dynamics In *Pr Nat Ac Sc India* p 280 (August 1936) the acceleration of one body relative to another body of comparable mass as well as its acceleration for actual motion in space were given

For relative motion the potential function is

$$V = \frac{G(M+m)}{r} + \frac{G(M+m)h^2}{c^2} \frac{1}{r^3}$$

where r is the distance between the two bodies M and m their masses, G the gravitational constant, h double the areal rate and c the velocity of light. This correctly yields the differential equation

$$\frac{d^2 u}{d\theta^2} + u = \frac{\mu}{h^2} + \frac{3\mu}{c^2} u^2$$

2. Prof Tullio Levi-Civita in the *American Journal of Mathematics* (Vol LIX No 2, April 1937, pp 225—231) has also treated the extra effect as

'first order perturbations', and following Newtonian principles and adopting the classical integral of energy and areas deduced certain Astronomical consequences of Relativistic Two-Body Problem.

He has found that for two bodies of comparable masses, the trajectory may be considered to be that of a central force with the potential function for relative motion (in our notations) as

$$V = \frac{G(M+m)}{r} + 3 \left\{ 1 - \frac{1}{2} \frac{Mm}{(M+m)^2} \right\} \frac{G^2(M+m)^2}{c^2 r^2} + \frac{1}{2} \frac{Mm}{(M+m)^2} \cdot \frac{c^2 h^2}{G^2(M+m)^2} \cdot \frac{G^3(M+m)^3}{c^4 r^3} \quad (52'1)$$

He has then concluded that the first term represents the Newtonian attraction, and the other two (both of the second order) are the relativistic perturbations varying according to the inverse cube and the inverse fourth power respectively of the distance, and has then inferred that by putting one of the masses equal to zero we get $3 \frac{G^2 M^2}{c^2 r^2}$ for the perturbative function of the Einsteinian one-centre problem (p. 229). The angular precession (per revolution) of the periastron in the case of a double star turns out to be the same as the precision for an infinitesimal planet moving about a central mass possessing the total mass of the binary system

$$\Delta \omega = \frac{6\pi G^2 (M+m)^2}{c^2 h^2} \quad (52'2)$$

3. (1) It can, however, be pointed out that the extra terms do not, in fact, represent the Einsteinian perturbation. (*Phil. Mag.*, Vol. XXVII, January, 1939.)

For an infinitesimal planet we put $m=0$, and obtain from the above potential function the acceleration by differentiation as

$$f = -\frac{GM}{r^2} - \frac{6G^2 M^2}{c^2 r^3} \quad \text{only}$$

which is
$$= \frac{d^2 r}{dt^2} - r \left(\frac{d\theta}{dt} \right)^2$$

Substituting $r = \frac{1}{u}$ and therefore $\frac{d^2 r}{dt^2} = -h^2 u^2 \cdot \frac{d^2 u}{d\theta^2}$

as with Levi-Civita, $r^2 \frac{d\theta}{dt} = h$,

we get
$$-h^2 u^2 \left[\frac{d^2 u}{d\theta^2} + u \right] = -GMu^2 - \frac{6G^2 M^2}{c^2} u^3$$

or
$$\frac{d^2 u}{d\theta^2} + u = \frac{GM}{h^2} + \frac{6G^2 M^2}{c^2 h^2} u \quad (52'3)$$

This is not at all identical with Einstein's equation in which the last term contains u^2 and not u .

Putting $\sqrt{1 - \frac{6G^2 M^2}{c^2 h^2}} = k$; $kh = h'$ and $k\theta = \theta'$ the equation becomes

$$\frac{d^2 u}{d\theta'^2} + u = \frac{GM}{h'^2}$$

which has the Newtonian and not the Einsteinian form, and for which the solution is

$$u = \frac{GM}{h'^2} + A \cos(\theta' + B), \text{ where } A \text{ and } B \text{ are constants.} \quad (52'4)$$

This is a complete ellipse revolving round the centre of force in a forward direction, which was known to Newton.

4. The consequences of this new law have been treated by me in detail in the *Proceedings of the National Institute of Sciences, India*, Vol. IV, pp. 337—40 (1938).

It has also been shown there that his further conclusion that the centre of gravity of a double star system has a net acceleration is contrary to the result of the New Theory.

5. It may be further pointed out that Levi-Civita has taken "the *absolute* motion of the centres of mass of a double star", supposed that "everything has been reduced to *ordinary space* . . . with reference to some *fixed or Galilean frame*" and has "employed the *classical integrals of energy and areas*"; and bringing "*relative* motion also under the Lagrangian Scheme" he has "applied the Lagrangian operator to the Newtonian constant of energy, regarding it a genuine constant of energy to a first approximation." (pp. 225 - 7). The potential function obtained by him for the motion is for a trajectory of a *central force*. He has calculated the angular precision of the periastron by the *ordinary* method of Newtonian Dynamics. In view of all these, for transforming his function into a differential equation the areal relation $r^2 \frac{d\theta}{dt} = h$ has been appropriately adopted.

6. As Levi-Civita has not followed the method of Relativity, in which $r^2 \frac{d\theta}{dt} = h \left(1 - \frac{2\mu}{c^2 r}\right)$, his law of force is of course different from that obtained by the Relativistic areal relation.

(1) For a one-body problem, Levi-Civita's law of radial force is

$$R = -\frac{\mu}{r^2} - \frac{6\mu^2}{c^2 r^3} \quad (52'5)$$

(2) Eddington in his *Relativity*, § 44, p. 97, has deduced the radial and transverse forces as

$$R = -\frac{\mu}{r^2} + \frac{2\mu^2}{c^2 r^3} + \frac{\mu}{c^2 r^2} \left\{ 3 \left(\frac{dr}{dt} \right)^2 - 2 \left(r \frac{d\theta}{dt} \right)^2 \right\}$$

$$Q = + \frac{2\mu}{c^2 r} \frac{dr}{dt} \cdot \frac{d\theta}{dt} \quad (52'6)$$

(3) De Sitter has obtained slightly different expressions (*Monthly Notices*, Vol. 76, p. 723, equations (3)).

(4) Jean Chazy in his *Theorie De La Relativite*, Vol. I. p. 101, has found the forces as

$$-\frac{\mu}{r^2} \left(1 - \frac{2\mu}{c^2 r} + \frac{2r^2}{c^2} - \frac{2r'^2}{c^2} - \frac{r'^2}{c^2 - \frac{2\mu}{r}} \right)$$

where $r = \sqrt{x^2 + y^2}$, $r' = \frac{rx' + yy'}{\sqrt{x^2 + y^2}}$, $r = \sqrt{x'^2 + y'^2}$

x' and y' being derivatives with regard to time;

$$\text{and} \quad \frac{2\mu r'}{r^2 \left(c^2 - \frac{2\mu}{r} \right)} \quad (52'7)$$

7. It will thus be seen that while in Relativity the next biggest term in the radial force is a repulsive force $+\frac{2\mu^2}{c^2 r^3}$, in Levi-Civita's formula the corresponding term is an attractive force $-\frac{6\mu^2}{c^2 r^3}$. It is the difference in its magnitude which enabled him to obtain the correct value for the advance of the periastron by the Newtonian method.

8. But Levi-Civita's law would not yield the correct value for the deflection of light.

$$\epsilon = \frac{1}{c^2 R_0} \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \left[-\frac{\mu}{r^2} - \frac{6\mu^2}{c^2 r^3} \right] r^2 \cos \psi d\psi$$

where $r \cos \psi = R_0$

$= \frac{2\mu}{c^2 R_0}$, the Newtonian value, the second term being negligible.

9. The spectral shift of light also will remain constant from the centre to the edge of the Sun.

SECTION IV

HIGHER APPROXIMATION

1. Einstein's equation of orbital motion in a gravitational field was deduced in Ch. XIII, pp. 275-79, without his postulates, and both with and without his method and a more general form of the latter was also given in Ch. XV App, pp. 86-7. The same equation can be deduced in a somewhat different way.

In a non-gravitational field the kinetic energy remains constant and so

$$\left(\frac{dr}{dt}\right)^2 + \left(r\frac{d\theta}{dt}\right)^2 = C.$$

In a gravitational field if Newton's inverse square law were exact and independent of the motions of bodies

$$\left(\frac{dr}{dt}\right)^2 + \left(r\frac{d\theta}{dt}\right)^2 = C + \frac{2\mu}{r}$$

where μ is the product of the gravitating mass of the centre and some constant.

If the law of gravitation were only approximately and not exactly Newtonian (the velocity of gravitation being finite), we would have

$$(1+f_1) \left(\frac{dr}{dt}\right)^2 + (1+f_2) \left(r\frac{d\theta}{dt}\right)^2 = C + \frac{2\mu}{r} (1+f_3) \quad (53'1)$$

as the most appropriate form which would approach the Newtonian form as r increases. The last term corresponds to the retarded potential. Here, as on p. 86, the unknown functions f 's must be independent of θ if the gravitational influence is nearly uniform in all directions round the origin, and they must contain μ as a factor, because the influence must be proportional to the mass. Hence they are functions of r only, and can by Laurent's theorem be expressed in descending powers of r .

$$\begin{aligned} \text{Therefore } \left(1 + \mu \sum_1 \frac{A_n}{r^n}\right) \left(\frac{dr}{dt}\right)^2 + \left(1 + \mu \sum_1 \frac{B_n}{r^n}\right) \left(r\frac{d\theta}{dt}\right)^2 \\ = C + \frac{2\mu}{r} \left(1 + \mu \sum_1 \frac{C_n}{r^n}\right) \dots \end{aligned}$$

where A 's, B 's and C 's are constants. (53'2)

As the sigmas are small fractions, we can divide throughout by the coefficient of the first term and get the form

$$\left(\frac{dr}{dt}\right)^2 + \left(1 + \mu \sum_1 \frac{P_n}{r^n}\right) \left(r\frac{d\theta}{dt}\right)^2 = C + \frac{2\mu}{r} \left(1 + \mu \sum_1 \frac{Q_n}{r^n}\right),$$

where P 's and Q 's are constants.

The force being central practically (see Sec. IX) $r^2 \frac{d\theta}{dt} = h$. Dividing throughout by the square of these we get,

$$\left(\frac{1}{r^2} \frac{dr}{d\theta} \right)^2 + \left(1 + \frac{\mu P_1}{r} + \frac{\mu P_2}{r^2} + \dots \right) \frac{1}{r^2} = \frac{C}{h^2} + \frac{2\mu}{h^2 r} \left(1 + \frac{\mu Q_1}{r} + \frac{\mu Q_2}{r^2} + \dots \right)$$

or $\left(\frac{du}{d\theta} \right)^2 + (1 + \mu P_1 \cdot u + \mu P_2 \cdot u^2 + \dots) u^2$

$$= \frac{C}{h^2} + \frac{2\mu}{h^2} (1 + \mu Q_1 \cdot u + \mu Q_2 u^2 + \dots) u \quad (53'3)$$

Differentiating and dividing by $2 \frac{du}{d\theta}$, we get,

$$\frac{d^2 u}{d\theta^2} + u + \frac{3}{2} \mu P_1 \cdot u^2 + 2\mu P_2 u^3 + \dots = \frac{\mu}{h^2} (1 + 2\mu Q_1 \cdot u + 3\mu Q_2 u^2 + 4\mu Q_3 u^3 + \dots) \quad (53'4)$$

In rapidly descending series the first terms predominate, hence

$$\frac{d^2 u}{d\theta^2} + u + \frac{3\mu P_1}{2} \cdot u^2 = \frac{\mu}{h^2} + \frac{2\mu^2 Q_1}{h^2} \cdot u \text{ nearly.} \quad (53'5)$$

2. Of course in a non-gravitational field $\frac{d^2 u}{d\theta^2} + u = 0$, which gives the straight line $u = \frac{\cos \theta}{R}$.

3. In a gravitational field, the first approximation is $\frac{d^2 u}{d\theta^2} + u = \frac{\mu}{h^2}$ which is Newton's equation for the law of acceleration $-\frac{\mu}{r^2}$.

4. The second approximation (which can be inferred from Sec. IX where it will be shown that the retarded potential differs from the Newtonian only in second order terms) is

$$\begin{aligned} \frac{d^2 u}{d\theta^2} + u &= \frac{\mu}{h^2} - \frac{3\mu P_1}{2} \cdot u^2 \\ &= \frac{\mu}{h^2} + \frac{3\mu}{D^2} u^2, \text{ where } -\frac{P_1}{2} = \frac{1}{D^2}. \end{aligned}$$

$$\text{This as shown on p. 279 gives the law as } -\frac{\mu}{r^2} - \frac{3\mu h^2}{D^2} \cdot \frac{1}{r^4}. \quad (53'6)$$

where D is found to be the velocity of gravitation equal to that of light.

5. The third approximation is

$$\frac{d^2 u}{d\theta^2} + u = \frac{\mu}{h^2} - \frac{3\mu P_1}{2} \cdot u^2 + \frac{2\mu^2 Q_1}{h^2} \cdot u,$$

from which the law of acceleration is

$$-h^2 u^2 \left(\frac{d^2 u}{d\theta^2} + u \right) = -\frac{\mu}{r^2} - \frac{3\mu h^2}{D^2} \cdot \frac{1}{r^4} - \frac{2\mu^2 Q_1}{r^3} \dots \quad (53'7)$$

But by putting $\sqrt{1 - \frac{2\mu^2 Q_1}{h^2}} = k$; $k\theta = \theta'$ and $kh = h'$, we can transform the equation into

$$\frac{d^2 u}{d\theta'^2} + u = \frac{\mu}{h'^2} - \frac{3\mu P_1}{2h'^2} \cdot u^2,$$

which is of the Einsteinian form, giving a rotation of the orbit.

6. In the same way higher approximations can be obtained from

$$\frac{d^2 u}{d\theta^2} + u + \sum_1^\infty \left\{ \frac{n+2}{2} \cdot P_n \cdot u^{n+1} \right\} = \frac{\mu}{h^2} + \frac{\mu^2}{h^2} \sum_1^\infty \left\{ (n+1) Q_n u^n \right\}.$$

7. From the equation in the form

$$\left(\frac{du}{d\theta} \right)^2 = R_0 + R_1 u + R_2 u^2 + \dots + R_n u^n + \dots$$

the orbit is given by $\theta = \pm \int \frac{du}{\sqrt{R_0 + R_1 u + R_2 u^2 + \dots}} + \text{constant}$ (53'8)

When u is small and the R 's are also small, the integration can be easily effected by expansion.

8. Even if the areal rate be not constant and $r^2 \frac{d\theta}{dt} = h \left(1 + \sum_1^\infty \frac{R_n}{r^n} \right)$ the equation of (53'5) will retain its form. The second approximation will retain its own form if h is constant to the first order term.

9. The following possible law of gravitation is also obvious:—

$$- \frac{\mu}{r^2} - s \cdot \frac{3\mu h^2}{D^2} \cdot \frac{1}{r^4} - (1-s) \frac{6\mu^2}{D^2} \cdot \frac{1}{r^3}$$

where $0 \leq s \leq 1$ (53'9)

This gives the correct value for the advance of the perihelion for all values of s .

If $s=0$, the deflection of light is Newtonian, but the spectral shift of light is Einsteinian both at the centre and the edge.

If $s=1$, the deflection of light and also the spectral shift from the centre and the edge are as already predicted in the previous chapters.

If s has other values, the deflection of light and the spectral shift from the edge are both reduced in the ratio of s as compared to the predicted values.

But as the retarded potential differs from the Newtonian only in second order terms $s=1$, nearly.

SECTION V

TWO ATTRACTING BODIES

In Relativity "the double star problem is still unsolved" (Eddington's *Relativity*, Note 8, p. 248). No such difficulty exists in our theory.

1. *Relative Motion.*

(1) By applying to the Sun and the planet velocity and acceleration equal and opposite to those of the Sun we reduce the Sun to rest. The acceleration of the planet relative to the Sun then becomes $-\frac{(M+m)}{SP^2} - \frac{3G(M+m)h^2}{D^2} \cdot \frac{1}{SP^4}$, which is a combination of the inverse square and the inverse fourth power of the distance.

The effect is as if the whole mass were concentrated at the Sun. The same rule will apply even if the law of acceleration be $\sum \frac{\mu_n}{r^n}$.

(2) It is thus clear that for *relative* motion all the equations and formulæ previously obtained for an infinitesimal planet become automatically applicable, if the two masses be regarded as being concentrated at the Sun. Hence, all that is necessary for a two-body problem is to substitute $G(M+m)$ for μ in all the results.

2. *Absolute Motion.*

(1) The actual motions of the two bodies in space are given by the motion of the centre of gravity added to their motions relative to the centre of gravity.

We know that $\frac{M}{m} = \frac{GP}{GS}$

and so $\frac{M}{M+m} = \frac{GP}{SP}$ and $\frac{m}{M+m} = \frac{GS}{SP}$.

Hence (as shown in Ch. XIII, p. 280) the acceleration of the planet due to the Sun is

$$= -\frac{GM}{SP^2} - \frac{3GMh^2}{D^2} \cdot \frac{1}{SP^4} = -\frac{GM^3}{(M+m)^2} \cdot \frac{1}{GP^2} - \frac{3GM^5h^2}{D^2(M+m)^2} \cdot \frac{1}{GP^4}$$

Similarly, the acceleration of the Sun due to the planet is

$$= -\frac{Gm^3}{(M+m)^2} \cdot \frac{1}{GS^2} - \frac{3Gm^5h^2}{D^2(M+m)^2} \cdot \frac{1}{GS^4}$$

where h stands for twice the common areal rate. Thus both the Sun and the planet move as if certain masses are concentrated at the centre of gravity.

(2) On the Newtonian principle of action and reaction being equal and opposite the force exerted on the planet is

$$= -\frac{GM^3m}{(M+m)^2GP^2} - \frac{3GM^5mh^2}{D^2(M+m)^2} \cdot \frac{1}{GP^4} \quad \dots \quad (54.1)$$

= -the force exerted by the planet on the centre of gravity.

The force exerted on the Sun is

$$= -\frac{Gm^3M}{(M+m)^2GS^2} - \frac{3Gm^5Mh^2}{D^2(M+m)^2} \cdot \frac{1}{GS^4} \quad \dots \quad (54.2)$$

= -the force exerted by the Sun on the centre of gravity.

But from the relation $\frac{M}{m} = \frac{GP}{GS}$, it is obvious that the two pulls on the centre of gravity exactly balance each other.

Hence, there is no net acceleration of the Centre of Gravity at all, if the masses are regarded as concentrated in points S and P.

This result contradicts Levi-Civita's conclusion.

SECTION VI

RESTRICTED THREE BODIES PROBLEM

For simple cases of Three Bodies Problem, the ordinary methods used in celestial measures can be easily adapted to the new law of Gravitation. For the more general case the potential function was obtained in Ch. XIII, Sec. II, para 6.

1. The Motion of a Satellite.

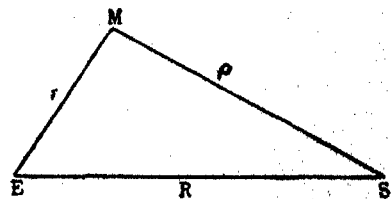
Suppose the Moon's orbit relative to the Earth and that of the Earth relative to the Sun are both nearly circular.

Taking the origin at the Earth E and the moving axis of ξ towards the Sun S, and reducing the Earth to rest the relative motion of the Moon M can be easily found. From Ch. XIII, Sec. II, § 6, p. 280, the accelerations along the moving axis acting on the Moon are

$$\frac{G(E+M)}{r^2} \left(1 + \frac{3h^2}{D^2 r^2} \right) \text{ along ME,}$$

$$\text{and } \frac{G.S}{R^3} \left(1 + \frac{3H^2}{D^2 r^2} \right) \text{ along SE,}$$

$$\text{and } \frac{G.S}{\rho^2} \left(1 + \frac{3H'^2}{D^2 r^2} \right) \text{ along MS.}$$



But the component accelerations of the Sun's apparent motion, assumed to be nearly circular, (i.e., $\frac{d\theta}{dt} = \omega$) are

$$\left. \begin{aligned} \frac{d^2 \xi}{dt^2} - 2\omega \frac{d\eta}{dt} - \omega^2 \xi \\ \frac{d^2 \eta}{dt^2} + 2\omega \frac{d\xi}{dt} - \omega^2 \eta \end{aligned} \right\} \dots \dots \dots (55'1)$$

and

Multiplying these by $\frac{d\xi}{dt}$ and $\frac{d\eta}{dt}$ respectively, and then adding and integrating we get

$$\frac{1}{2} \left\{ \left(\frac{d\xi}{dt} \right)^2 + \left(\frac{d\eta}{dt} \right)^2 \right\} - \frac{\omega^2}{2} (\xi^2 + \eta^2)$$

and this is equal to the sum of the potentials.

$$\frac{G(E+M)}{r} \left(1 + \frac{h^2}{D^2 r^2} \right) + \frac{GS}{\rho} \left(1 + \frac{H'^2}{D^2 \rho^2} \right) + \frac{GS}{R^2} \left(1 + \frac{H^2}{D^2 R^2} \right) \xi + C,$$

where $\rho^2 = \xi^2 + \eta^2$, and $R = \text{constant}$.

Also $\frac{GS}{R} = (R\omega)^2$ nearly.

Accordingly,

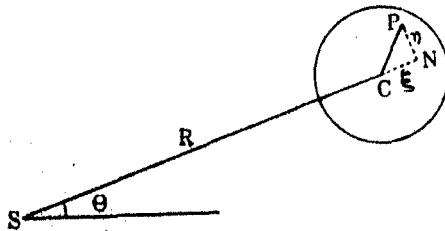
$$\begin{aligned} \frac{1}{2} v^2 = & \frac{G(E+M)}{r} \left(1 + \frac{h^2}{D^2 r^2} \right) + \frac{R^3 \omega^2}{\rho} \left(1 + \frac{H'^2}{D^2 \rho^2} \right) \\ & + \frac{\omega^2}{2} \left[\left\{ \xi - R \left(1 + \frac{H^2}{D^2 R^2} \right) \right\}^2 + \eta^2 \right] \\ & + \left\{ C - \frac{R^2 \omega^2}{2} \left(1 + \frac{H^2}{D^2 R^2} \right)^2 \right\} \quad \dots \quad (55'2) \end{aligned}$$

The initial conditions will determine whether

$$C - \frac{R^2 \omega^2}{2} \left(1 + \frac{H^2}{D^2 R^2} \right)^2 \text{ is positive or negative.}$$

2. Comet.

Let the Sun S with mass S be taken as the fixed origin, not being affected by a small comet in space, C the centre of gravity of the spherical comet of radius b consisting of an aggregation or swarm of particles. (R, θ) are the polar coordinates of C



referred to S , (ξ, η) the coordinates of P referred to C as origin, the axis of ξ being the prolongation of R . If the swarm be not rotating round its own centre then its internal attraction follows the Newtonian formula nearly and would be $Gm\sqrt{\xi^2 + \eta^2}$.

If X and Y be the components of the accelerations due to S then with regard to the moving axes, the equations of motion of P are

$$\begin{aligned} \frac{d^2(R+\xi)}{dt^2} - (R+\xi) \left(\frac{d\theta}{dt} \right)^2 - \frac{1}{\eta} \frac{d}{dt} \left(\eta^2 \frac{d\theta}{dt} \right) \\ = X - G \frac{m}{b^3} \xi. \end{aligned} \quad (55'3)$$

$$\begin{aligned} \frac{d^2\eta}{dt^2} - \eta \left(\frac{d\theta}{dt} \right)^2 + \frac{1}{(R+\xi)} \frac{d}{dt} \left\{ (R+\xi)^2 \frac{d\theta}{dt} \right\} \\ = Y - \frac{Gm}{b^3} \eta. \end{aligned} \quad (55'4)$$

But

$$\begin{aligned} X &= \frac{-GS}{(R+\xi)^2 + \eta^2} - \frac{3GS}{[(R+\xi)^2 + \eta^2]^{\frac{3}{2}}} \cdot \frac{h^2}{c^2} \cdot \frac{R+\xi}{\sqrt{(R+\xi)^2 + \eta^2}} \\ Y &= \frac{-GS}{(R+\xi)^2 + \eta^2} - \frac{3GS}{[(R+\xi)^2 + \eta^2]^{\frac{3}{2}}} \cdot \frac{h^2}{c^2} \cdot \frac{\eta}{\sqrt{(R+\xi)^2 + \eta^2}} \end{aligned}$$

But as ξ and η are very small as compared to R,

$$X = -\frac{GS}{R^3} \left\{ 1 + \frac{3h^2}{c^2 R^2} \left(1 - \frac{2\xi}{R} \right) \right\} \left(1 - \frac{2\xi}{R} \right) \text{ nearly} \quad (55'5)$$

$$Y = -\frac{GS}{R^3} \left\{ 1 + \frac{3h^2}{c^2 R^2} \left(1 - \frac{3\xi}{R} \right) \frac{\eta}{R} \right\} \left(1 - \frac{2\xi}{R} \right) \text{ nearly} \quad (55'6)$$

The equations being true for all values of ξ , η would also be true for C where $\xi = \eta = 0$. Hence, when terms are expanded in powers of ξ , η , all the terms independent of ξ , η must cancel out.

$$\text{Hence } \frac{d^2\xi}{dt^2} - 2\frac{d\eta}{dt} \frac{d\theta}{dt} - \eta \frac{d^2\theta}{dt^2} - \xi \left(\frac{d\theta}{dt} \right)^2 = \frac{2GS}{R^3} \left(1 + \frac{3h^2}{c^2 R^2} \right) \xi - \frac{Gm\xi}{b^3}$$

$$\frac{d^2\eta}{dt^2} + 2\frac{d\xi}{dt} \frac{d\theta}{dt} + \xi \frac{d^2\theta}{dt^2} - \eta \left(\frac{d\theta}{dt} \right)^2 = \frac{2GS}{R^3} \left(1 + \frac{9h^2}{2c^2 R^2} \right) \eta - \frac{Gm\eta}{b^3}$$

nearly.

$$\text{If the orbit is circular } R = \text{constant and } \omega^2 = \left(\frac{d\theta}{dt} \right)^2 = \frac{GS}{R^3}.$$

$$\begin{aligned} \text{So } \left\{ \begin{aligned} \frac{d^2\xi}{dt^2} - 2\omega \frac{d\eta}{dt} + \left\{ \frac{Gm}{b^3} - \frac{3GS}{R^3} \left(1 + \frac{2h^2}{c^2 R^2} \right) \right\} \xi &= 0 \\ \frac{d^2\eta}{dt^2} + 2\omega \frac{d\xi}{dt} + \left\{ \frac{Gm}{b^3} - \frac{3GS}{R^3} \left(1 + \frac{3h^2}{c^2 R^2} \right) \right\} \eta &= 0 \end{aligned} \right\} \quad (55'7) \end{aligned}$$

The motion being approximately periodic, we can put

$$\xi = A \cos (pt + \alpha) \text{ and } \eta = B \sin (pt + \alpha)$$

Substituting we get

$$-p^2 \cdot A \cos(pt + \alpha) - 2\omega p \cdot B \cos(pt + \alpha) \\ + \left\{ \frac{Gm}{b^3} - \frac{3GS}{R^3} \left(1 + \frac{2h^2}{c^2 R^2} \right) \right\} A \cos(pt + \alpha) = 0$$

and

$$-p^2 \cdot B \sin(pt + \alpha) - 2\omega p \cdot A \sin(pt + \alpha) \\ + \left\{ \frac{Gm}{b^3} - \frac{3GS}{R^3} \left(1 + \frac{3h^2}{c^2 R^2} \right) \right\} A \sin(pt + \alpha) = 0$$

or

$$\left[p^2 - \left\{ \frac{Gm}{b^3} - \frac{3GS}{R^3} \left(1 + \frac{2h^2}{c^2 R^2} \right) \right\} \right] A \cos(pt + \alpha) + 2\omega p \cdot B \sin(pt + \alpha) = 0.$$

$$2\omega p \cdot A \sin(pt + \alpha) + \left[p^2 - \left\{ \frac{Gm}{b^3} - \frac{3GS}{R^3} \left(1 + \frac{3h^2}{c^2 R^2} \right) \right\} \right] B \cos(pt + \alpha) = 0.$$

The determinantal equation is

$$\left[p^2 - \left\{ \frac{Gm}{b^3} - \frac{3GS}{R^3} \left(1 + \frac{2h^2}{c^2 R^2} \right) \right\} \right] \times \left[p^2 - \left\{ \frac{Gm}{b^3} - \frac{3GS}{R^3} \left(1 + \frac{3h^2}{c^2 R^2} \right) \right\} \right] \\ - 4 \cdot p^2 \cdot \frac{GS}{R^3} = 0.$$

The left-hand side is positive when $p = \pm \infty$ and negative when either of the brackets vanishes.

For periodicity and stability the roots of the quadratic equation should be real and positive.

SECTION VII

A NEW STATICS

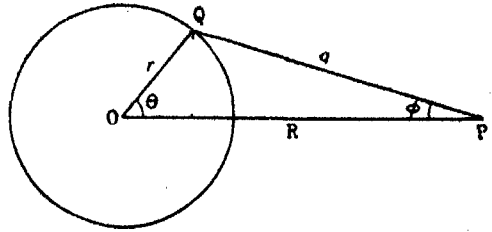
1. The Relativity results of gravitation involve a serious fallacy. As only one centre problem is soluble in it, the assumption has been made that the effect is the same as if the whole mass were concentrated at the centre of a ring or a sphere. But this is true only in the Newtonian inverse square law and not for the different law of Relativity.

For the new law of gravitation a new Statics, just as a new Dynamics, has to be built up. If the attracting Sun and the attracted body were both stationary, $h=0$, and so the Newtonian law will apply. But in Nature, all Heavenly bodies are in relative motion.

2. A Circular Ring revolving round an external point in its plane.

If a ring with centre O and radius r be revolving round an axis perpendicular to its plane and passing through an external point P, then every point Q on the ring will have the same angular velocity, say ω . Let $OP=R$, $QP=q$ and $\angle POQ=\theta$ and $\angle OPQ=\phi$. Then the areal rate of Q is $h_1=q^2\omega$ while $h=R^2\omega$;

$$\text{hence } h_1^2 = \frac{q^4}{R^4} \cdot h^2$$



The mass of the element at Q = $\frac{d\theta}{2\pi} \cdot M$, where M is the whole mass of the ring.

Also $q^2 = R^2 + r^2 - 2Rr \cos \theta$ and $r^2 = R^2 + q^2 - 2Rq \cos \phi$.

Then the component along OP of the attraction of the mass element at Q on P is

$$\begin{aligned} F_q &= -\frac{GM}{2\pi} d\theta \cdot \left[\frac{1}{q^3} + \frac{3h_1^2}{c^2 q^4} \right] \cos \phi \\ &= -\frac{GM}{2\pi} \cdot \left[\frac{1}{q^3} + \frac{3h^2}{c^2 R^4} \right] \cdot \frac{q^2 + R^2 - r^2}{2Rq} \end{aligned}$$

Hence the total attraction of the ring is

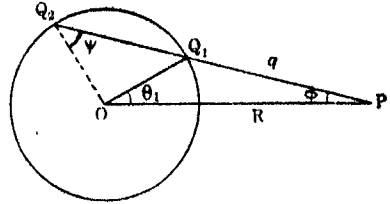
$$\begin{aligned} F &= -\frac{GM}{4\pi R^2} \int_0^{2\pi} \left\{ 1 + \frac{3h^2}{c^2 R^4} (R^2 - r^2) \right\} \left(1 - \frac{2r}{R} \cos \theta + \frac{r^2}{R^2} \right)^{-\frac{1}{2}} \\ &\quad + \frac{3h^2}{c^2 R^4} \left(1 - \frac{2r}{R} \cos \theta + \frac{r^2}{R^2} \right)^{\frac{1}{2}} \\ &\quad + \frac{(R^2 - r^2)}{R^2} \left(1 - \frac{2r}{R} \cos \theta + \frac{r^2}{R^2} \right)^{-\frac{3}{2}} \Big] d\theta \\ &= -\frac{GM}{2R^2} \left[\left\{ 1 + \frac{3h^2}{c^2 R^4} \left(1 - \frac{r^2}{R^2} \right) \right\} \left(1 + \frac{1}{2} \frac{r^2}{R^2} \right) \right. \\ &\quad + \frac{3h^2}{c^2 R^4} \left(1 + \frac{1}{2} \frac{r^2}{R^2} \right) \\ &\quad + \left. \left(1 - \frac{r^2}{R^2} \right) \left(1 + \frac{3}{2} \frac{r^2}{R^2} \right) \right] \\ &= -\frac{GM}{R^2} \left[1 + \frac{3h^2}{c^2 R^4} + \frac{1}{2} \frac{r^2}{R^2} - \frac{1}{2} \frac{h^2 r^2}{c^2 R^4} \right] \quad (561) \end{aligned}$$

3. A Circular Ring (another method).

Let PQ_1Q_2 cut the ring, where $PQ_1 = q_1$ and $PQ_2 = q_2$.

Let $\angle POQ_1 = \theta_1$ and $\angle POQ_2 = \theta_2$, and $\angle OQ_1Q_2 = \psi$.

$$\text{Then } \frac{q_1 d\phi}{r d\theta_1} = \frac{q_2 d\phi}{r d\theta_2} = \cos \psi.$$



Also $R \sin \phi = r \sin \psi$ and so $R \cos \phi d\phi = r \cos \psi d\psi$ and $\cos \phi = (1 - \frac{r^2}{R^2} \sin^2 \psi)^{\frac{1}{2}}$.

$$\text{Again } q^2 - 2R \cos \phi \cdot q + (R^2 - r^2) = 0,$$

Hence the two positive roots q_1 and q_2 of this equation are given by $q = R \cos \phi \pm \sqrt{R^2 \cos^2 \phi - (R^2 - r^2)} = R \cos \phi \pm r \cos \psi$.

Now if M be the mass of the ring then the mass elements at Q_1 and Q_2 are $\frac{M d\theta_1}{2\pi}$ and $\frac{M d\theta_2}{2\pi}$.

Accordingly the attraction of these two elements on P resolved along OP is

$$\begin{aligned} F_{q_1} + F_{q_2} &= -\frac{GM}{2\pi} \left[\left\{ \frac{1}{q_1^2} + \frac{3h^2}{c^2 q_1^4} \right\} d\theta_1 + \left\{ \frac{1}{q_2^2} + \frac{3h^2}{c^2 q_2^4} \right\} d\theta_2 \right] \cos \phi \\ &= -\frac{GM}{2\pi R} \left[\left(\frac{1}{q_1} + \frac{1}{q_2} \right) + \frac{3h^2}{c^2 R^4} (q_1 + q_2) \right] d\psi \\ &= -\frac{GM}{\pi R^2} \left(\frac{1}{1 - \frac{r^2}{R^2}} + \frac{3h^2}{c^2 R^2} \right) \left\{ 1 - \frac{1}{2} \frac{r^2}{R^2} \sin^2 \psi - \frac{1}{8} \frac{r^4}{R^4} \sin^4 \psi + \dots \right\} d\psi \end{aligned}$$

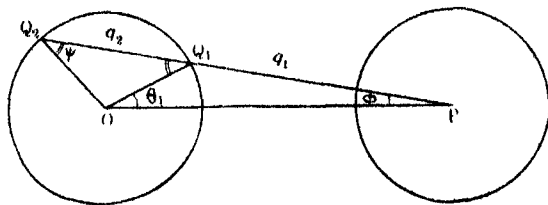
Hence the attraction at P due to both the halves of the ring is

$$\begin{aligned} F &= -\frac{2GM}{\pi R^2} \left\{ \frac{1}{1 - \frac{r^2}{R^2}} + \frac{3h^2}{c^2 R^2} \right\} \int_0^{\frac{\pi}{2}} \left\{ 1 - \frac{1}{2} \frac{r^2}{R^2} (1 - \cos 2\psi) - \frac{1}{8} \frac{r^4}{R^4} (\cos 4\psi - 4\cos 2\psi \right. \\ &\quad \left. + 3) + \dots \right\} d\psi \\ &= -\frac{GM}{R^2} \left(\frac{1}{1 - \frac{r^2}{R^2}} + \frac{3h^2}{c^2 R^2} \right) \left(1 - \frac{1}{4} \frac{r^2}{R^2} - \frac{1}{8} \frac{r^4}{R^4} + \dots \right) \\ &= -\frac{GM}{R^2} \left(1 + \frac{3h^2}{c^2 R^2} + \frac{1}{2} \frac{r^2}{R^2} - \frac{1}{4} \frac{h^2 r^2}{c^2 R^4} \right) \dots \dots \dots (56'2) \end{aligned}$$

4. Two Circular Rings.

Let the radii be a and r .

Then the attractions of the first ring with centre P , mass M_1 and radius a on the elements Q_1 and Q_2 on the second ring with mass M_2 , centre O and radius r , resolved along OP are respectively



$$-GM_1 \cdot \frac{M_2 d\theta_1}{2\pi} \left(\frac{1}{q_1^3} + \frac{3h_1^2}{c^2 q_1^4} + \frac{3a^2}{4q_1^4} - \frac{3a^2 h_1^2}{4c^2 q_1^6} \right) \cos \phi$$

and $-GM_1 \cdot \frac{M_2 d\theta_2}{2\pi} \left(\frac{1}{q_2^3} + \frac{3h_2^2}{c^2 q_2^4} + \frac{3a^2}{4q_2^4} - \frac{3a^2 h_2^2}{4c^2 q_2^6} \right) \cos \phi$

But $\cos \psi = \frac{q_1 d\phi}{rd\theta_1} = \frac{q_2 d\phi}{rd\theta_2}$ and $R \cos \phi d\phi = r \cos \psi d\psi$.

Hence the attraction between the first ring and the two elements on the second ring, when resolved along their line of centres is

$$\begin{aligned} F_{q_1} + F_{q_2} &= -\frac{GM_1 M_2}{2\pi} \cdot \frac{d\psi}{R} \left[\left(\frac{1}{q_1} + \frac{1}{q_2} \right) + \frac{3h^2}{c^2 R^4} (q_1 + q_2) + \frac{3a^2}{4} \left(\frac{1}{q_1^3} + \frac{1}{q_2^3} \right) \right. \\ &\quad \left. - \frac{3a^2 h^2}{4c^2 R^4} \left(\frac{1}{q_1} + \frac{1}{q_2} \right) \right] \\ &= -\frac{GM_1 M_2}{2\pi} \left[\left\{ \frac{1 - \frac{3h^2 a^2}{4c^2 R^4}}{1 - \frac{r^2}{R^2}} + \frac{3h^2}{c^2 R^2} \right\} \times \left\{ 1 - \frac{1}{2} \frac{r^2}{R^2} \sin^2 \psi - \frac{1}{8} \frac{r^4}{R^4} \sin^4 \psi + \dots \right\} \right. \\ &\quad \left. + \frac{3a^2}{4R^2} \cdot \frac{1}{\left(1 - \frac{r^2}{R^2} \right)^3} \left\{ \left(1 - \frac{3}{2} \frac{r^2}{R^2} \sin^2 \psi + \frac{3}{8} \frac{r^4}{R^4} \sin^4 \psi - \dots \right) \right\} \right. \\ &\quad \left. + \frac{3r^2}{R^2} (1 - \sin^2 \psi) \left\{ 1 - \frac{1}{2} \frac{r^2}{R^2} \sin^2 \psi - \frac{1}{8} \frac{r^4}{R^4} \sin^4 \psi \right\} \right] \end{aligned}$$

Hence the whole force between the two rings along their line of centres is

$$\begin{aligned} F &= -\frac{2GM_1 M_2}{\pi R^2} \int_0^{\pi} \left[\left(\frac{1 - \frac{3h^2 a^2}{4c^2 R^4}}{1 - \frac{r^2}{R^2}} + \frac{3h^2}{c^2 R^2} \right) \left\{ 1 - \frac{1}{2} \frac{r^2}{R^2} (1 - \cos 2\psi) \right. \right. \\ &\quad \left. \left. - \frac{1}{8} \frac{r^4}{R^4} (\cos 4\psi - 4\cos 2\psi + 3) \right\} \right] d\psi \end{aligned}$$

$$\begin{aligned}
& + \frac{3a^2}{4R^2} \cdot \frac{1}{\left(1 - \frac{r^2}{R^2}\right)^3} \left\{ 1 - \frac{r^2}{R^2}(1 - \cos 2\psi) + \frac{r^4}{R^4}(\cos 4\psi - 4\cos 2\psi + 3) \right\} \\
& + \frac{9a^2 r^2}{4R^4 \left(1 - \frac{r^2}{R^2}\right)^3} \left\{ 1 - \frac{r^2}{R^2}(1 - \cos 2\psi) - \frac{r^4}{R^4}(\cos 4\psi - 4\cos 2\psi + 3) \right\} \\
& - \frac{9^2 a^2 r^2}{4R^4 \left(1 - \frac{r^2}{R^2}\right)^3} \left\{ \frac{1}{2}(1 - \cos 2\psi) - \frac{r^2}{R^2}(\cos 4\psi - 4\cos 2\psi + 3) \right. \\
& \quad \left. + \frac{r^4}{R^4}(\cos 6\psi + \dots - 10) \right\} \Bigg| d\psi \\
& = -\frac{GM_1 M_2}{R^2} \left[1 + \frac{3h^2}{c^2 R^2} \left(1 - \frac{a^2 + r^2}{4R^2} \right) + \frac{3}{4} \cdot \frac{a^2 + r^2}{R^2} \right] \text{ nearly } \quad (56'3)
\end{aligned}$$

This result could have been written down straight off from that of one ring on considerations of symmetry.

5. The Attraction of a Spherical Shell on a moving point.

$$q \cos \psi = r \sin \phi \cos \phi$$

The mass element at Q =

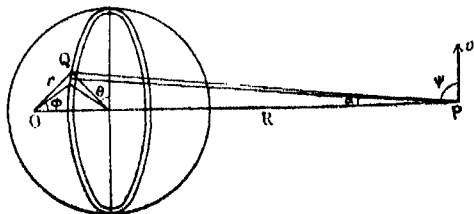
$$\rho r^2 dr \sin \phi d\phi d\theta.$$

$$h = R.v \text{ and } h_1 = q \sin \psi.v$$

$$\text{and so } h_1^2 = \frac{h^2}{R^2} (q^2 - r^2 \sin^2 \phi \cos^2 \alpha)$$

$$q^2 = r^2 - 2rR \cos \phi + R^2 \text{ and}$$

$$qdq = rR \sin \phi d\phi.$$



The attraction due to the element at Q along OP is

$$F_q = -G \rho r^2 dr \sin \phi d\phi d\theta \left\{ \frac{1}{q^2} + \frac{3h_1^2}{c^2 q^4} \right\} \cos \alpha.$$

$$= -G \rho r^2 dr \sin \phi d\phi d\theta \left\{ \frac{1}{q^2} + \frac{3h^2}{c^2 q^4 R^2} (q^2 - a^2 \sin^2 \phi \cos^2 \theta) \right\} \times \cos \alpha.$$

The attraction of the whole ring is

$$\begin{aligned}
F_r = & -G \rho r^2 dr \sin \phi d\phi \int_0^{2\pi} \left[\frac{1}{q^2} + \frac{3h^2}{c^2 R^2 q^2} \right. \\
& \left. - \frac{h^2 r^2 \sin^2 \phi}{c^2 q^4 R^2} (1 + \cos 2\theta) \right] d\theta.
\end{aligned}$$

$$\begin{aligned}
&= -\frac{G\rho r dr dq}{R^2} \cdot \pi \left[\left(1 + \frac{3h^2}{c^2 R^2}\right) + \left(1 + \frac{3h^2}{c^2 R^2}\right) \frac{R^2 - r^2}{q^2} - \frac{3h^2(R^2 + r^2)}{4c^2 R^4} \right. \\
&\quad \left. - \frac{3h^2(R^4 - r^4)}{4c^2 R^4 q^2} + \frac{3h^2(R^2 - r^2)^2}{8c^2 R^4 q^2} + \frac{3h^2(R^2 - r^2)^3}{8c^2 R^4 q^4} + \frac{3h^2 q^2}{8c^2 R^4} \right. \\
&\quad \left. + \frac{3h^2(R^2 - r^2)}{8c^2 R^4} \right] \quad (56'4)
\end{aligned}$$

Hence the attraction due to the whole shell is obtained by integrating from $(R-a)$ to $(R+a)$ with respect to q and is

$$F_s = -\frac{G\rho\pi}{R^2} \left[4 \left(1 + \frac{3h^2}{c^2 R^2}\right) r^2 - \frac{4h^2 r^4}{c^2 R^4} \right] dr \quad (56'5)$$

6. Attraction of a sphere on a moving particle.

The attraction of a whole sphere is obtained by integrating the above from 0 to a with respect to r and is

$$\begin{aligned}
F &= -\frac{4G\rho\pi}{R^2} \int_0^a \left[\left(1 + \frac{3h^2}{c^2 R^2}\right) r^2 - \frac{h^2 r^4}{c^2 R^4} \right] dr \\
&= -\frac{G\rho}{R^2} \cdot \frac{4}{3}\pi a^3 \left[1 + \frac{3h^2}{c^2 R^2} - \frac{h^2 a^2}{c^2 R^4} \right] \\
&= -\frac{GM}{R^2} \left(1 + \frac{3h^2}{c^2 R^2} - \frac{h^2 a^2}{c^2 R^4} \right)
\end{aligned}$$

where M is the mass of the whole sphere. (56'6)

(N.B.—This force function for a sphere had been obtained by me by an approximate method. The more rigorous proof substituted in the preceding paragraph 5 is due to Mr. Omar Ali Siddiqi.)

7. The mutual attraction of two spheres.

The mutual attraction has been obtained by taking the attraction of one sphere on a point on the second sphere and then integrating for the second sphere successively for ring, shell and then sphere.

For relative motion the force is

$$F = -\frac{GM_1 M_2}{R^2} \left[1 + \frac{3h^2}{c^2 R^2} \left(1 - \frac{a_1^2 + a_2^2}{5R^2} \right) \right] \quad (56'7)$$

8. Two spheres revolving round their common centre of gravity.

Obviously $M_1 R_1 = M_2 R_2$ and $R = R_1 + R_2$

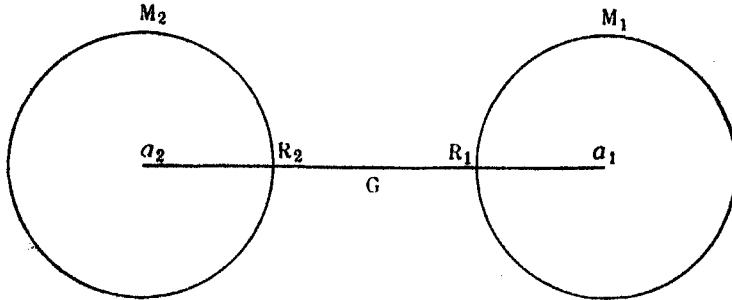
and so

$$\frac{1}{R} = \frac{M_1}{M_1 + M_2} \cdot \frac{1}{R_1}$$

Hence the acceleration of M_2 due to their mutual attraction is

$$f = -\frac{GM_1}{R^2} \left[1 + \frac{3h^2}{c^2 R^2} \left(1 - \frac{a_1^2 + a_2^2}{5R^2} \right) \right]$$

$$= -\frac{GM_1}{R_2^2} \cdot \frac{M_1^2}{(M_1 + M_2)^2} \left[1 + \frac{3h^2}{c^2 R_2^2} \cdot \frac{M_1^2}{(M_1 + M_2)^2} \left(1 - \frac{a_1^2 + a_2^2}{5R_2^2} \cdot \frac{M_1^2}{(M_1 + M_2)^2} \right) \right]$$



If w be the instantaneous angular velocity of the two centres round G , then $h_1 = R_1^2 w$; $h_2 = R_2^2 w$

and $h = (R_1 + R_2)^2 w$, from which $h = \left(\frac{M_1 + M_2}{M_1} \right)^2 \cdot h_2$

$$\text{Hence } f = -\frac{GM_1^3}{(M_1 + M_2)^2} \cdot \frac{1}{R_2^2} \left[1 + \frac{3(M_1 + M_2)^2 h_2^2}{c^2 M_1^2} \cdot \frac{1}{R_2^2} \right. \\ \left. \times \left(1 - \frac{a_1^2 + a_2^2}{5R_2^2} \cdot \frac{M_1^2}{(M_1 + M_2)^2} \right) \right] \quad (56'8)$$

SECTION VIII

APPLICATIONS OF THE LAW

1. The Spectral Shift.

(1) Taking (56'6) as the law of acceleration of a moving particle under the attraction of a sphere,

$$F = -\frac{GM}{r^2} \left[1 + \frac{3h^2}{c^2 r^2} - \frac{3h^2 a^2}{5c^2 r^4} \right]$$

Hence as in Ch. XIII Sec. IV (5), p. 285, the spectral shift from the edge of the Sun is

$$= \left[1 + \frac{2\mu}{c^2} \int_a \left(-\frac{1}{r^2} - \frac{3h^2}{c^2} \cdot \frac{1}{r^4} + \frac{3h^2 a^2}{5c^2 r^6} \right) dr \right]^{\frac{1}{2}} - 1 \text{ nearly}$$

$$= \frac{\mu}{c^2} \left(\frac{1}{a} + \frac{1}{a} - \frac{3}{25} \cdot \frac{1}{a} \right), \text{ as } h = ca, \text{ nearly.}$$

$$= \frac{47}{50} \cdot \frac{2\mu}{c^2 a} \quad (57'1)$$

= 88 per cent more than Einstein's value

(2) The spectral shift of light from any point on the Solar disc, according to the method in para (6), p. 286, is

$$\begin{aligned}
 &= \frac{\mu}{c^2 a} \left[1 + \left(1 - \frac{3}{25} \right) \sin^2 \alpha \right] \\
 &= \frac{\mu}{c^2 a} \left(1 + \frac{22}{25} \sin^2 \alpha \right) \quad \dots \quad (57'2)
 \end{aligned}$$

2. The Deflection of Light.

As in para (3) (ii), p. 284, the maximum deflection of light is

$$\epsilon = \frac{1}{c^2 R} \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \left[-\frac{\mu}{r^3} - \frac{3\mu h^2}{c^2 r^4} + \frac{3\mu h^2 a^2}{5c^2 r^6} \right] r^2 \cos \psi \, d\psi$$

where $h = cR$ nearly and $r \cos \psi = R$.

$$\begin{aligned}
 &= -\frac{\mu}{c^2 R} \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \left[\cos \psi + 3 \cos^3 \psi - \frac{3}{5} \cdot \frac{a^2}{R^2} \cos^5 \psi \right] d\psi. \\
 &= -\frac{\mu}{c^2 R} \left[2 + 4 - \frac{3}{80} \cdot \frac{a^2}{R^2} \cdot \frac{256}{15} \right] \\
 &= -\frac{6\mu}{c^2 R} \left(1 - \frac{8}{75} \cdot \frac{a^2}{R^2} \right),
 \end{aligned}$$

where a is the radius of the Sun, and R the shortest distance (57'3)

This equals $2''.33$ for stars in line with the edge.

It is thus obvious that the error in the previously announced value will diminish as one proceeds away from the edge. Thus so long as errors do not come in owing to the proximity to the edges of the plates, the value of deflection will increase the further the star is away from the Sun. (See my paper in *Current Science*, Vol. VII, p. 67, para 2.)

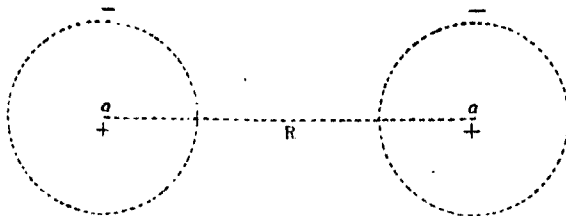
Owing to the corpuscular character of light, the further error will be the repulsion due to the pressure of light on light, which also will diminish as the inverse square of the distance when the star is further away. (See my paper in *Current Science*, Vol. VI, p. 458.)

3. The Advance of Perihelion.

The value remains practically the same as before, viz., $\frac{6\pi\mu^2}{c^3 h^2}$.

4. Cohesive Force between Atoms.

Consider two Hydrogen atoms with radii a and distance R apart. Each system has a negative electron revolving round the positive proton, while the system as a whole may be in motion. Each electron may approximately be regarded as a negatively charged circular ring with the line density $\frac{-e}{2\pi a}$, while the two protons are relative to their electrons practically stationary and have their charges $+e$ concentrated at the centres. If the protons are moving then the electrons will have a double motion—with the orbit and in the orbit.



With the help of the previous formulae, the forces between the two positive and two negative charges can be written down approximately as

$$\begin{aligned}
 &\text{between } + \text{ and } + && -\frac{e^2}{R^2} \left(1 + \frac{3H^2}{c^2 R^2} \right) \\
 &.. \quad + \quad .. \quad - && + \frac{e^2}{R^2} \left\{ 1 + \frac{3H^2}{c^2 R^2} + \frac{3h^2}{c^2 R^2} + \frac{3}{4} \frac{a^2}{R^2} - \frac{3}{4} \frac{h^2 a^2}{c^2 R^4} \right\} \\
 &.. \quad - \quad .. \quad + && + \frac{e^2}{R^2} \left\{ 1 + \frac{3H^2}{c^2 R^2} + \frac{3h^2}{c^2 R^2} + \frac{3}{4} \frac{a^2}{R^2} - \frac{3}{4} \frac{h^2 a^2}{c^2 R^4} \right\} \\
 &.. \quad - \quad .. \quad - && -\frac{e^2}{R^2} \left\{ 1 + \frac{3H^2}{c^2 R^2} + \frac{3h^2}{c^2 R^2} + \frac{3}{2} \frac{a^2}{R^2} - \frac{3}{2} \frac{h^2 a^2}{c^2 R^4} \right\}
 \end{aligned}$$

nearly

Hence the sum-total of all the four forces is

$$= + \frac{3h^2}{c^2 R^4} \cdot e^2, \text{ which has a net positive value} \quad (57.5)$$

Thus the necessary consequence of the new law is that even if electric attraction and repulsion between two opposite and similar unit charges, respectively, be exactly equal, there will still be a net small excess of attractive over repulsive forces between two atoms, manifesting itself as a cohesive force, for which no other explanation exists at present. The force will increase as h increases or R decreases, and can account for the combining of atoms into molecules.

SECTION IX

GRAVITATION UNIFIED WITH ELECTRICITY

1. Newton's conception was that gravitational force was exerted even at a long distance instantaneously and so it made no difference whether the affected body or the source was stationary or moving. This was unfortunately supposed to be confirmed by Laplace's deduction from planetary motions that the velocity of gravitation even if finite must be 6 million times that of light or more. As electrical waves were propagated with the velocity of light, it became impossible to identify gravitation with either electricity or light.

2. By the artificial device of introducing an imaginary fourth dimension of time, regardless of the unconvincing postulates the assumption involved, Einstein evolved his General Theory of Relativity so as to include gravitational phenomena, and to produce astronomical results as then known from observation. But in that theory the velocity of gravitation had no intrinsic meaning, as it depended merely on the choice of coordinates. Hence a unification of electromagnetic and gravitational phenomena was impossible. Attempts have since been made to devise some other artifice for obtaining a unified field theory to combine both. If electromagnetic phenomena are three-dimensional and not easily commensurable with Einstein's four-dimensional gravitational phenomena, the easiest idea was to go a step further and take a space of five dimensions which really by compounding and not unifying would have both these effects as particular cases. But as the fifth dimension did not manifest itself physically, a further arbitrary condition had to be introduced. As a purely mathematical exercise, the attempts have not been wholly infructuous, but as a physical concept they are an utter failure and only help to lead us one step further away from reality.

3. If Laplace's difficulty can be got over and the gravitational influence could have the same velocity as light or electric propagation, the position would be simplified and a complete unification of all these phenomena brought about. As shown in my paper on Gravitation [New Zealand Astronomical Society's publication "The Southern Stars", Vol. 3, Oct. 1937, p. 2. and p. 7] gravitational force can be the slight excess of electric attraction over electric repulsion. So far it has been arbitrarily assumed that the force between two equal and opposite unit charges is exactly equal and opposite to that between two equal and similar unit charges (Coulomb's law). But the two forces may be only nearly and not exactly equal in magnitude, the attracting force exceeding the repulsive force very slightly. In such a case the cumulative effect of the excess due to pairs of atoms in two bodies will evidence itself as an attractive gravitational force between them, which however would be extremely small as compared to electric force.

It has already been shown in Ch. XIII that Einstein's four-dimensional continuum is really a partial misinterpretation of spherical wave propagation. If it is nothing but an electric wave propagation, then from the well-known formula of Lienard and Wiechert for the retarded electric potential $\left[\frac{e}{r \left(1 - \frac{v_r}{c} \right)} \right]$ for a moving charge, it can be seen that to the first order the value remains unaltered in spite of the lapse of time.

THE FORMULA FOR THE RETARDED POTENTIAL.

4. Eddington in his Relativity (Note 10, pp. 252-53) has obtained a formula giving the potential at time t in terms of the positions and the strengths of the source at the time $(t-\tau)$. But unfortunately he has taken the velocity of propagation as unity, which conceals its true significance. Consider a fixed point P at time t , and a moving source S at time $(t-\tau)$, the distance PS being given as a function of $(t-\tau)$, so that

$$PS = r = f(t-\tau)$$

Then the component velocity of S along SP is

$$v_r = - \frac{dr}{dt} = - f'(t-\tau).$$

Suppose that the wave emitted from S at time $(t-\tau)$ has at time t reached a point Q, while travelling with velocity D in the direction SP, then

$$PQ = \rho = D \cdot \tau - r = D \cdot \tau - f(t-\tau).$$

Thus ρ and τ are functions of each other.

By differentiating,

$$1 = D \cdot \frac{d\tau}{d\rho} + f'(t-\tau) \frac{d\tau}{d\rho} = D \left(1 - \frac{v_r}{D} \right) \frac{d\tau}{d\rho}.$$

Hence if $V(t-\tau)$ be any quantity associated with the source S at the time $(t-\tau)$

$$\left\{ \frac{V}{r \left(1 - \frac{v_r}{D} \right)} \right\}_{t-\tau} = D \cdot \frac{V(t-\tau)}{f(t-\tau)} \cdot \frac{d\tau}{d\rho} = D \cdot \frac{d}{d\rho} F(t-\tau)$$

where

$$F' = - \frac{V}{f}.$$

The approximate value of τ required in calculating a retarded potential is given by the condition that Q coincides with P, i.e., $\rho = 0$.

$$\text{Hence } \left[\frac{V}{r \left(1 - \frac{v_r}{D}\right)} \right] = D \cdot \left\{ \frac{d}{d\rho} F(t-\tau) \right\}_{\rho=0}$$

where the square brackets indicate the antedated value.

By Lagrange's theorem on the expansion of implicit functions, writing $(t-\tau) = \left(t - \frac{\rho}{D}\right) - \frac{1}{D} f(t-r)$, we have

$$\begin{aligned} F(t-\tau) &= F\left(t - \frac{\rho}{D}\right) - F'\left(t - \frac{\rho}{D}\right) \cdot \frac{f\left(t - \frac{\rho}{D}\right)}{D} - \sum_2^{\infty} \frac{1}{n!} \frac{\partial^{n-1}}{\partial \rho^{n-1}} \left[F'\left(t - \frac{\rho}{D}\right) \left\{ \frac{f\left(t - \frac{\rho}{D}\right)}{D} \right\}^n \right] \\ &= F\left(t - \frac{\rho}{D}\right) + \frac{V\left(t - \frac{\rho}{D}\right)}{D} + \sum_2^{\infty} \frac{D^{n-1}}{n!} \frac{\partial^{n-1}}{\partial \rho^{n-1}} \left[V\left(t - \frac{\rho}{D}\right) \frac{\left\{ f\left(t - \frac{\rho}{D}\right) \right\}^{n-1}}{D^n} \right] \end{aligned}$$

$$\text{But } D \frac{\partial}{\partial r} = \frac{\partial}{\partial t}$$

Hence substituting we get

$$\begin{aligned} \left[\frac{V}{r \left(1 - \frac{v_r}{D}\right)} \right] &= D \cdot \left\{ \frac{d}{d\rho} F(t-\tau) \right\}_{\rho=0} = - \frac{\partial}{\partial t} \left\{ F(t-\tau) \right\}_{\rho=0} \\ &= - F'(t) - \frac{1}{D} \cdot \frac{dV(t)}{dt} \\ &\quad + \sum_2^{\infty} - \frac{(-1)^n}{n!} \frac{d^{n-1}}{dt^{n-1}} \left[V(t) \cdot \frac{\{f(t)\}^{n-1}}{D^n} \right] \\ &= \frac{V}{r} - \frac{1}{D} \frac{dV}{dt} + \sum_2^{\infty} \frac{(-1)^n}{n!} \cdot \frac{1}{D^n} \frac{d^n}{dt^n} (r^{n-1} \cdot V) \end{aligned}$$

where on the right r and V are to be taken for the time t (57.1)

5. If the gravitating source were stationary, a static potential field would be established. But the great Heavenly bodies are themselves in motion; so the principle of retarded potential must be applied. It was pointed out in Ch. VI, Sec. II, para 10, p. 130, that Laplace was quite wrong in concluding that unless the velocity of gravitation was enormously large, the tangential component would cause much larger perturbations than are actually observed, because the effect of the first order term is really compensated for by the effect of the retarded potential.

For the gravitational potential $V=M$, the constant mass of the sun. Hence the first order term $-\frac{1}{D} \frac{dV}{dt}$ vanishes, and the next smaller terms which constitute a very rapidly diminishing series would not cause the disturbance which had worried Laplace. Laplace's objection therefore becomes ineffectual if the gravitational potential behaves analogously to electrical potential, much more so if gravitational and electrical potentials are really identical.

It follows that if S and P were two attracting particles, then, to the first order term, P will be attracted in the direction P'S and not its displaced direction P'S', in spite of the gravitational influence being propagated with a finite velocity equal to that of electric wave propagation, *i.e.*, of light. In particular as for the Sun V_r is small, the force of attraction on Mercury remains almost radial despite the finiteness of the gravitational velocity. Thus the difficulty experienced in the earlier chapters (the method of which has been abandoned) disappears and a resisting medium is not required to counteract perturbations not observed.

Taking the potential function in the New Theory as $\frac{M}{r} + \frac{Mh^2}{D^2} \cdot \frac{1}{r^3}$, its retarded value is

$$\left[\frac{M + \frac{Mh^2}{D^2} \cdot \frac{1}{r^3}}{r \left(1 - \frac{V_r}{D}\right)} \right] = \frac{M}{r} + \frac{Mh^2}{D^2} \cdot \frac{1}{r^3} + \frac{M}{2D^2} \cdot \frac{d^2 r}{dt^2},$$

neglecting terms containing $\frac{1}{D^3}$ and smaller terms, which represent a rapidly diminishing series (57'2)

Hence the acceleration to the first order effect is

$$\begin{aligned} &= -\frac{M}{r^2} - \frac{3Mh^2}{D^2} \cdot \frac{1}{r^4} + \frac{M}{2D^2} \frac{d^2 r}{dt^2} \cdot \frac{dr}{dt}, \text{ where the last term is negligible.} \\ &= -\frac{M}{r^2} - \frac{3Mh^2}{D^2} \cdot \frac{1}{r^4}. \end{aligned} \quad (57'3)$$

Accordingly for practical purposes the law of gravitation remains unaltered.

Light has already been shown (Chs. XIV and XV) to be an electromagnetic system. The unification of Gravitation, Light and Electricity is now complete. It is therefore no wonder that all have the same velocity of propagation.

SECTION X

THE PROBLEM OF THE RED SHIFT OF THE SOLAR SPECTRUM

In the *Observatory*, October, 1937, pages 266—271, a paper of J. Evershed, under the above title was published in which on page 270 he kindly referred to my theory that a light corpuscle consists of a binary system with components of

equal mass and opposite charges, rotating round each other and travelling forward with the velocity of light; which leads to the spectral shift of light from the edge of the Sun being twice Einstein's value, my formula being $(1 + \sin^2 \alpha)$ times Einstein's value, where α is the angle between the line of sight and the radius of the Sun meeting the point from which light is observed. The deflection of light from stars past the Sun on my theory lies between 1.3 and 1.5 times Einstein's value. Evershed conceded that these predictions appeared to be confirmed by his measures of the iron lines in the red and by Freundlich's observed value of the deflection of stars, but announced that the displacements of the sodium D lines at the limb of the Sun and at the centre have precisely the Einstein value.

His fuller paper "The Red Shift of the D Lines of Sodium in the Sun" (Monthly Notices of the R. A. S., Vol. 98, No. 3, January, 1938, p. 195) however shows that (1) the calcium lines H_β , K_β , like the iron lines, give displacements at the edge, which are double of Einstein's value, and still larger values at the centre

but (2) sodium lines D_1 (not D_2) show no substantial difference between the last centre and the limb.

In the *Observatory*, Vol. 61, p. 298, November, 1938, I have pointed out why the last result cannot yet be accepted as reliable.

It is submitted that the true test of Einstein's value can be furnished only by measurements of the spectral shift of lines at the edge of the Sun in the red region least subject to refrangibility, preferably at the time of a total or annular solar eclipse, when the scattering due to light from the centre would be nil.

So far Royds alone has made measurements of the spectral shift of solar light at a total solar eclipse. His observations were at the centre and near the edge at distances from the centre: '28, '57, '76, '90, '95 and '97 times the Sun's radius. They undoubtedly establish that the shift has a tendency of increase as one proceeds from near the centre towards the Edge, and that it is double of Einstein's value at the Edge. At the centre itself the values are unreliable on account of the high dispersion used. (*Monthly Notices*, Vol. 97, pp. 692—95 and *Nature*, Vol. 140, July 3, 1937, pp. 12-13.)

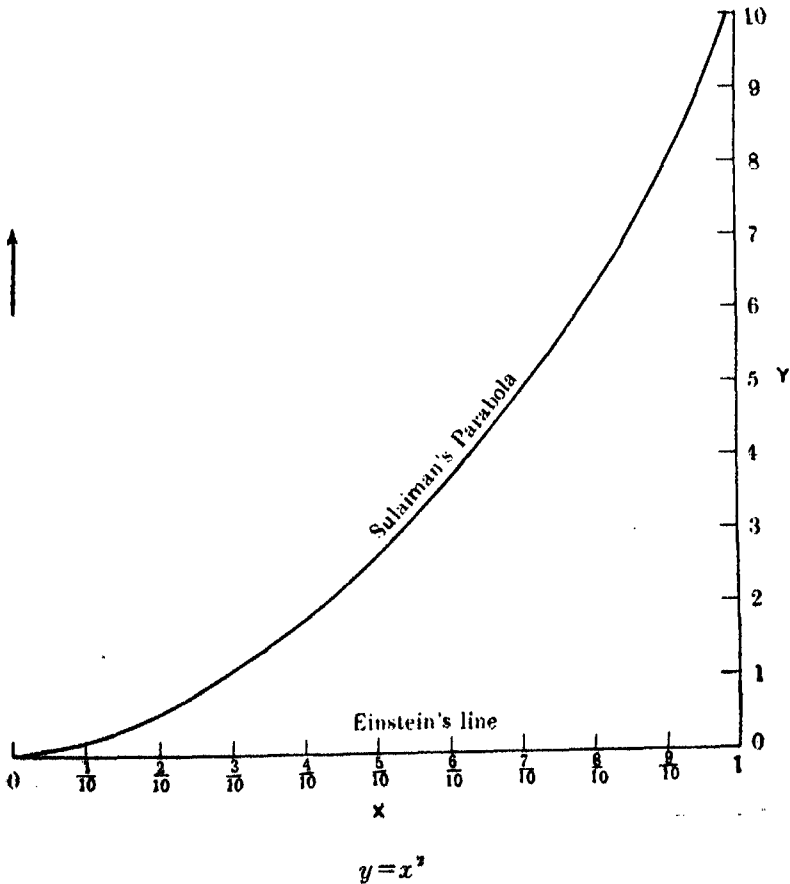
I previously pointed out that owing to various causes there is a deficiency in the measurements; up to half the distance from the centre the values, though gradually increasing, are below Einstein's theoretical value; and for the other half, they are above it, and still gradually increasing. Unfortunately the method adopted so far had been to take a mean of all values from the centre to the edge, which obviously conceals the otherwise patent fact that the spectral shift is not the same at all points, as Einstein's theory would suggest, but that there is undoubtedly a rapid and progressive increase as one proceeds from the centre towards the Edge. As shown by me at the Science Congress (January 5, 1938), this effect would become

prominent if a curve were drawn for the difference between the spectral shift at any point and that at the centre.

The New Theory of Light gives a natural explanation of the spectral shift of nebulae as being due to an inherent loss of frequency with the passage of time, without assigning to them tremendous velocities of recession.

THE SOLAR SPECTRAL SHIFT CURVES

From (57'2) $\Delta\lambda - \Delta\lambda_0 = \frac{22}{25} \cdot \frac{\mu}{c^2 \alpha} \cdot \sin^2 \alpha$, which is a parabola in shape.



CONTRIBUTION TO THE MORPHOLOGY OF *OROBANCHE* *AEGYPTIACA* PERS.

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(With eight figures in the text and plates I, II and III)

SUMMARY

1. The origin and development of the floral members on the thalamus is in the usual acropetal order.
2. There are four anther-lobes. The archesporium is a hypodermal layer in each anther-lobe.
3. A single sporogenous band is differentiated from the archesporium which gives rise to the spore mother-cells. These undergoing the usual stages of development, give rise to the pollen-grains.
4. The haploid number of chromosomes at the metaphase stage of the first reduction division is nineteen.
5. The pollen-grain is two-celled at the time of shedding.
6. Numerous anatropous ovules, each with a single massive integument, are formed on four parietal placentas. The development of the ovules is of the usual type. The hypodermal archesporial cell functions directly as the megaspore mother-cell without cutting off any wall cell.
7. The megaspore mother-cell by two successive divisions gives rise to a linear tetrad; the embryo-sac arises from the chalazal one, while the other three degenerate.
8. The mature embryo-sac is of the normal type. It contains one egg, two synergids, the fusion nucleus and the three antipodal cells which soon degenerate although their remains persist for long.
9. The endosperm is of the cellular type. The embryo-sac is divided into two chambers by a transverse wall. The next division in the micropylar chamber is longitudinal and subsequently transverse walls are laid down towards the micropylar end, cutting off the two micropylar haustorial cells. The middle cells by subsequent divisions form a mass of endosperm tissue.
10. In some ovules, the micropylar chamber elongates and divides transversely separating off at the micropylar end the cell that will give rise to the micropylar haustoria. Further transverse divisions take place in the middle cell. Subsequently longitudinal walls are laid down giving rise to an endosperm as is observed in the former case.
11. The chalazal chamber becomes binucleate and functions as a chalazal haustorium. Sometimes 3-4 nuclei are seen in this cell which becomes divided by an oblique wall. It is almost inactive but persists for a long time. The micropylar haustoria are active during the early stages of the embryo development. Both are differentiated from the primary endosperm chambers.
12. The oospore elongates and divides by a transverse wall into the suspensor cell and the embryo cell. The suspensor is elongated, sometimes consisting of a number of cells. The embryo cell further divides by longitudinal and transverse walls.
13. The nutritive jacket originates from the integumental cells immediately adjacent to the degenerating nucellus. After fertilisation, it completely surrounds the embryo-sac. Its cells are often binucleate. It is similar to and serves the same function as the anther-tapetum.

INTRODUCTION

On account of the parasitic habit and consequently of the general biological interest of *Orobanche* and allied genera, the family Orobanchaceæ has been subjected to repeated investigations both from the morphological and biological viewpoints. The earliest morphological work was on *Christisonia* (Worsdell),¹⁴ which however dealt only with the development of the ovule. Carter³ found that the megaspore mother-cell in *O. minor* developed in the same way as described for *Scrophularia marylandica* (Schertz).¹¹ Glišić⁷ reported that the embryo-sac development in *O. hederæ* and *O. gracilis* was of the normal type while the formation of the endosperm and haustoria was like that seen in Scrophulariaceæ. He concluded that the Scrophulariaceæ and Orobanchaceæ are closely allied to each other. Cassera⁴ also noted the great resemblances of the Orobanchaceæ to the Scrophulariaceæ in a number of characters. Juliano⁸ described the anatomy and morphology of the vegetative and reproductive organs of *Aeginetia indica* Linn., an important root-parasite on the sugarcane plants in the Philippines.

MATERIAL AND METHODS

The plant is a total root-parasite, commonly found throughout the plains of India. It is an annual, parasitic on several members of the Crucifereæ and Solanaceæ. It appears in the month of November and continues to flower till the end of March, when the plant dies after producing the fruits and seeds. The material was collected at Allahabad in the fourth week of November, 1937. The ovaries showing various stages of development were divested of the sympetalous corolla, including the epipetalous stamens. The longer ones were cut transversely and longitudinally to facilitate penetration of the fixative. It was found necessary to exhaust air from the material by suction as it did not sink in the fixative. Various fixatives were used but Langlet's modification of Nawaschin's fluid⁶ proved most successful. Sections were cut at 6-10 microns and were stained both in safranin, gentian violet, Orange G and iron-alum haematoxylin, often counter-stained with Orange G. The latter was the most suitable combination and gave good results.

THE FLOWER

The scape bears numerous flowers, closely arranged in racemose order. They are bracteate and pedicellate. The corolla is bilabiate and blue in colour. There are four stamens which are didynamous and epipetalous. The ovary is bicarpellary, ovoid, unilocular throughout. There are four lamellate parietal placentas. Numerous anatropous ovules of very small size are borne on these placentas.

ORGANOGENY OF THE FLOWER

The origin and development of the floral members is in the usual acropetal manner (Text-figs. 1-4). The appearance of a papilla in the axil of a bract is the

first evidence of the formation of a flower. The papilla is in the form of a hemispherical mass of meristematic cells, terminating the floral axis. As it increases in size, the calyx is the first to make its appearance as an annular outgrowth at its base. The corolla comes next and then the stamens. As there are only four stamens, often only one is seen on one side in longitudinal section (Text-figs. 3-4). The tip of the floral axis is used up in the formation of the carpels. As they develop, they become narrowed at the apex and fuse to form the style and stigma (Text-figs. 5-6).



Figs. 1-4. Longitudinal sections of flower buds showing stages in organogeny. $\times 29$. Figs. 5-6. Longitudinal sections of ovary in early stages of development. $\times 29$.

THE ANTHER AND DEVELOPMENT OF POLLEN-GRAINS

The young anther shows four distinct lobes in transverse section. In the young condition all the cells of the anther are alike. Later a hypodermal layer is differentiated under each lobe to form the archesporium, which thus consists of a plate of cells (Pl. I, fig. 1). This divides into an inner-sporogenous layer and an outer-primary parietal layer. The cells of the sporogenous layer divide once or twice to form the microspore mother-cells, which are arranged in the form of a crescent-shaped band as seen in transverse section (Pl. I, fig. 2). They are easily distinguished from the surrounding cells by the density of their cytoplasm and their conspicuous nuclei. The primary parietal layer divides by tangential walls into three layers. The innermost layer, in contact with the sporogenous layer becomes the tapetum (Pl. I, fig. 3). Its cells have prominent nuclei and in the later stages become bi- or even tri-nucleate due to mitotic divisions of the nucleus at the time the microspore mother-cells are in synizesis (Pl. I, fig. 6). The outermost layer beneath the epidermis becomes the endothecium. There is one intermediate layer, whose cells become flattened and crushed due to the expansion of the cells both within and without.

In the resting stage the nucleus of the microspore mother-cell shows a fine reticulum, composed of a large number of deeply staining bodies (Pl. I, fig. 4). The

first sign of the entry of the nucleus into the meiotic prophase is indicated by an increase in its size accompanied by the formation of a system of chromatin threads. These become more and more prominent during succeeding stages and finally occupy the whole of the nuclear cavity, spreading in the form of a loose tangle (Pl. I, fig. 5). This is the leptotene stage of the meiotic division. Later the cytoplasm of the mother-cell begins to shrink from the cell wall. Just within the nuclear membrane, a narrow zone of clear area is formed, from the inside of which a series of delicate fibres make their appearance, which constitute the spindle. The fibres attach themselves to the bivalents, which are nineteen in number (Pl. I, fig. 7). Carter³ reported the same number in *O. minor*. The daughter chromosomes then travel to the two poles. No cell-plate is formed after the first division (Pl. I, fig. 8). There is a small interval of interkinesis but very soon the daughter nuclei prepare themselves for the next division. Another set of spindles is initiated which may be arranged either at right angles to each other or lie parallel, the former being the more common condition (Pl. I, figs. 9, 10).

The four nuclei, formed after reduction division in the pollen-mother-cell, become separated from one another by furrowing to give rise to four microspores, all of which are functional (Pl. I, fig. 11). The original cell-wall of the mother-cell is present up to this stage and the tetrads are embedded in the mucilaginous coat (Pl. I, fig. 12) which eventually dissolves and the microspores are liberated (Pl. I, fig. 13). The young microspores then round off and acquire their own coats (Pl. I, fig. 14). Long before dehiscence, the nucleus of the microspore is divided into two (Pl. I, fig. 15). Before the division is to commence, the nucleus lies at one end of the cell, while the other end is vacuolate with only a thin layer of cytoplasm along the wall. The generative cell which is adjacent to the wall is much smaller than the vegetative (Pl. I, fig. 16). This is the shedding stage of the male gametophyte (Pl. I, fig. 17).

THE OVULE AND THE DEVELOPMENT OF THE EMBRYO-SAC

The flowers are strongly protandrous and the ovules begin to arise from the placenta only at the time when the microspores are fully formed. The nucelli appear as small papillæ, formed by the activity of the cells of the placenta (Text-fig. 7). The single hypodermal archesporial cell becomes recognisable at an early stage by its large size and conspicuous nucleus, much before the integument makes its appearance (Pl. II, fig. 18). No parietal cell is cut off and it functions directly as the megaspore mother-cell, thus conforming to the general rule among the Sympetalæ. The nucellus is single-layered.

The subsequent enlargement of the megaspore mother-cell is accompanied by differentiation of the single integument which eventually becomes several layers

thick. As a result of quicker growth of the cells on one side, the ovules gradually bend over towards the opposite side, finally becoming completely anatropous (Text-fig 8).

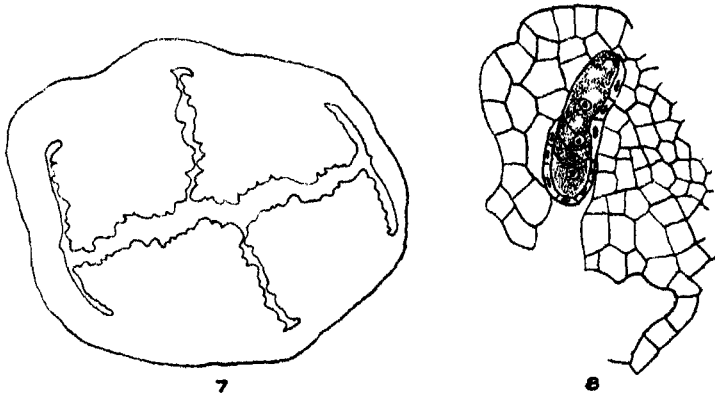


Fig. 7. Transverse section of the ovary showing four parietal placentas. $\times 44$.

Fig. 8. Longitudinal section of the ovule showing single layer of nucellus and massive integument. $\times 400$.

The megaspore mother-cell then elongates and undergoes two consecutive divisions, giving rise to a row of four megaspores. The one towards the chalazal end is the functional megaspore (Pl. II, figs. 19, 20). Degeneration of the other three megaspores does not follow a definite course. It usually proceeds from the micropylar end towards the chalazal, but sometimes the second degenerates only after the micropylar and sub-chalazal (Pl. II, figs. 21, 22).

The development of the embryo-sac conforms to the normal type. The functional megaspore enlarges and becomes vacuolated (Pl. II, fig. 21). Its nucleus begins to divide quite early and the daughter nuclei migrate to the opposite poles of the enlarged embryo-sac. Both divide again simultaneously, giving rise to the four-nucleate embryo-sac. A large vacuole now occupies the middle of the sac (Pl. II, fig. 23), which continues to enlarge and finally destroys all the nucellar cells lying around it. These four nuclei divide again (Pl. II, figs. 24, 25) and the normal eight-nucleate embryo-sac is formed (Pl. II, fig. 26). By this time the nucellus has almost disappeared, although traces of it are seen as dark masses or streaks along the side of the sac.

The mature embryo-sac is elongated in outline with its broader end towards the micropyle (Pl. II, fig. 26). At the micropylar end lies the egg-apparatus consisting of an egg and two synergids. The egg is larger than either of the synergids and lies in between them at a slightly lower level with a big vacuole towards the apex. The synergids are elongated and more or less pyriform with

prominent nuclei and basal vacuoles (Pl. II, fig. 27). The two prominent polar nuclei lie in the middle of the sac below the egg, and fuse to form the fusion nucleus (Pl. II, fig. 28). There are three antipodals at the extreme chalazal end which begin to degenerate very early, although their remains persist for a very long time even up to the formation of the endosperm (Pl. III, figs. 34, 38, 41).

ENDOSPERM

Among the Orobanchaceae, the cellular type of endosperm has been reported in *Christisonia* (Worsdell)¹, *Phelipaea coerulea* (Bernard)¹, *O. cymosa* (Persidsky)¹⁰, *O. hederæ* and *O. gracilis* (Glišić)⁷, *O. uniflora* (Cassera)⁴ and in *Aeginetia indica* (Juliano)⁸.

In accordance with the statements of previous authors, endosperm development in *O. aegyptiaca* is also of the cellular type.

The first division of the primary endosperm nucleus, which takes place much earlier than the division of the oospore, is followed by a transverse wall which divides the sac into two chambers, the micropylar and the chalazal (Pl. III, fig. 35). The nucleus of the micropylar chamber moves upwards and rests in the vicinity of the oospore. The nucleus of the chalazal endosperm chamber moves down and divides to form two nuclei which lie very close together. No wall is formed between them and this binucleate cell normally functions as the chalazal haustorium without undergoing any further division (Pl. III, fig. 36). Occasionally 3-4 nuclei are seen in this cell which thus becomes divided by an oblique wall (Pl. III, figs. 37, 38).

Further development of the endosperm takes place in the micropylar chamber. The first division is by a longitudinal wall and subsequently transverse walls are laid down cutting off the two micropylar haustorial cells from the rest of the endosperm (Pl. III, fig. 36). At this stage there are five endosperm cells the binucleate chalazal cell (acting as a haustorium) the two elongated micropylar cells which give rise to the haustoria, and the two endosperm proper cells in the middle. These last undergo further divisions, both transverse and longitudinal, to form a mass of endosperm tissue. In older stage the endosperm cells press into the antipodal end of the sac and the chalazal haustorium is reduced to a small pouch-like structure (Pl. III, figs. 39, 40).

There is another type of endosperm formation seen here, though it is less common. This differs from the former only in its early stages while the later stages for both the types are the same. Both are frequently seen in adjoining ovules of the same ovary. After the first division of the primary endosperm nucleus by a transverse wall, the micropylar chamber elongates and divides transversely, cutting off at the upper end the cell that will give rise to the micropylar haustoria. Further

transverse divisions take place in the middle cell (Pl. III, fig. 41). Longitudinal walls are formed afterwards and further development is repeated as in the former type.

HAUSTORIA

The two micropylar haustorial cells soon elongate and divide rapidly. The apical part of the haustoria, which is active, consists of two cells. These elongate considerably and form processes which branch freely and bend downwards into the tissue of the integument which thus is a source of nutritive supply to the embryo. These have prominent nuclei and dense protoplasm. The lower part consists of two longitudinal rows of small plate-like cells. Towards the base, these broaden and pass into the true endosperm. The haustoria are prominent only during the early stages of embryo development (Pl. III, figs. 39, 40).

The chalazal haustorium is not active and soon shows signs of degeneration.

NUTRITIVE JACKET

This originates from the cells of the integument, immediately adjacent to the degenerating nucellus. During early development of endosperm, the cells are elongated with their long axes perpendicular to the embryo-sac and are binucleate. These cells grow remarkably large and soon become vacuolated (Pl. III, figs. 35, 41). This is similar to the tapetal layer in the anther and probably serves the same function.

EMBRYO

The oospore remains dormant until the endosperm is almost completely formed. The first sign of development is a slight elongation of this cell (Pl. II, fig. 29). This divides by a transverse wall into two cells, the embryo proper and the suspensor. The suspensor is an elongated structure and sometimes consists of a number of cells (Pl. II, fig. 30). It is finally absorbed and disappears. The embryo cell further divides by longitudinal and transverse walls and follows the normal sequence of a dicot embryo (Pl. II, figs. 31, 32, 33).

GENERAL CONCLUSIONS

The more important embryological data on the family are summarised below:—

Anther:— In general the development of the anther is quite normal but in *Aeginetia indica* (Juliano)⁸ only two microsporangia are seen in transverse section. After reduction division cytokinesis of the microspore mother-cell takes place by furrowing. Two-celled pollen-grains have been observed in *Epiphegus virginiana* (Cook and Schreyer)⁵, *Aeginetia indica* (Juliano)⁸ and in *O. aegyptiaca* by the present writer.

Ovule :—The nucellus is reduced to a single layer of cells as in most of the Sympetalæ. There is a single massive integument whose innermost layer forms the nutritive jacket, which directly surrounds the embryo-sac.

Archegonium :—The hypodermal archegonial cell functions directly as the megaspore mother-cell. Parietal tissue is absent.

Embryo-sac :—Normal tetrad formation has been observed in *Christisonia* (Worsdell)¹⁴, in *O. minor* (Carter)³, in *O. uniflora* (Cassera)⁴, in *Aeginetia indica* (Juliano)⁸, and in *O. aegyptiaca* by the writer. The only exception is in *Aphyllon uniflorum* (*Orobanche uniflora*) in which Miss Smith¹³ failed to find any division of the mother-cell. This is evidently incorrect since on re-investigation Cassera⁴ has found normal tetrad formation in the same species. The chalazal megaspore functions and forms a normal 8-nucleate embryo-sac. Conflicting statements have been made about the antipodals. In *O. minor* (Carter)³ they are ephemeral and soon degenerate long before the time of fertilisation. In *O. uniflora* (Cassera)⁴, *Aeginetia indica* (Juliano)⁸ and *O. aegyptiaca*, they are present at the time of fertilisation and afterwards degenerate but their remains persist for long during the development of embryo and endosperm.

Endosperm :—The endosperm is cellular and, as noted by Cassera,⁴ it may arise in either of the two ways, designated as type A and type B. In the former, which is the commonest, the first division in the micropylar chamber is longitudinal, followed by transverse divisions, separating off the micropylar haustorial cells from the middle cells which give rise to the endosperm tissue. In type B the micropylar chamber divides transversely to cut off a micropylar cell (destined to give rise to the micropylar haustoria), and the middle cell which undergoes some further transverse divisions followed by longitudinal ones, to give rise to the body of the endosperm.

Type A has alone been reported in *O. hederæ* and *O. gracilis* (Glišić)⁷, and in *Aeginetia indica* (Juliano)⁸. Cassera⁴ has observed both types in *O. uniflora* and the writer in *O. aegyptiaca*, although type A is commoner. Glišić⁷ is of opinion that type A is the only method of development and doubts the observations made by Worsdell,¹⁴ Koch⁹ and Bernard¹ that type B is seen in the Orobanchaceæ. The writer agrees with the opinion of Cassera that both the types of development are seen in the Orobanchaceæ and it may differ in different species or both may occur in the same species.

Micropylar haustoria :—From the study of the endosperm development, it is clear that the micropylar haustoria in these plants arise from the endosperm and not from synergids as was once believed by Schlotterbeck.¹² As observed and reported by Glišić,⁷ Koch⁹ and also the writer in *O. aegyptiaca*, the micropylar haustoria are formed of a fertile part which is active and consists of two elongated cells forming processes in the integument, and the sterile part consisting of two longitudinal rows

of cells passing into regular endosperm tissue. The haustoria are prominent in the early stages of the embryo development only and later on degenerate.

Chalazal haustoria.—Soon after its initiation the chalazal chamber becomes binucleate. It elongates and directly functions as the chalazal haustorium. Cassera⁴ observed that it is active in the early development of endosperm. He described it as an organ representing a stunted haustorium which, contrary to the conditions found in Scrophulariaceæ and other Sympetalæ, never becomes prominent nor as highly developed as the micropylar haustoria. The writer has also observed the same in *O. aegyptiaca*, and agrees with the observation made by Cassera.⁴ Sometimes the chalazal chamber has 3-4 nuclei, and it is divided by an oblique wall. This is comparable with the large cell in the basal part of the endosperm with 2-4 nuclei, observed by Persidsky¹⁰ in *O. cumana* and *O. ramosa*.

Towards the later stages of endosperm formation, the chalazal haustorium begins to degenerate. The writer agrees with Cassera⁴ that this is probably due to the pressure exerted by the aggressive endosperm tissue and Persidsky's¹⁰ view, that the nuclei mass together in the chalazal haustorium and by their own impetus cause the rapid degeneration of the haustorium, is not acceptable.

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EXPLANATION OF PLATES I, II AND III ILLUSTRATING GIRJA DAYAL SRIVASTAVA'S
PAPER ON THE MORPHOLOGY OF *Orobancha aegyptiaca* PERS.

PLATE I

- Fig. 1. Transverse section (a part) of the anther, showing a single layer of hypodermal archesporium. $\times 775$.
 Fig. 2. Sporogenous tissue in the anther-lobes; the parietal layer has cut off the tapetum on the inner side. $\times 400$.
 Fig. 3. Sporogenous tissue, tapetum and other wall layers. $\times 775$.
 Fig. 4. Microspore mother-cell with nucleus in resting stage. $\times 1250$.
 Fig. 5. Same, leptotene stage. $\times 1250$.
 Fig. 6. Spore mother-cells in synezyses; tapetal cells are binucleate. $\times 400$.
 Fig. 7. Polar view of first metaphase, showing nineteen bivalents. $\times 1250$.
 Fig. 8. Interkinesis after first division. $\times 1250$.
 Figs. 9, 10. Two conditions in the disposition of spindles for the second division. $\times 1250$.
 Fig. 11. Formation of peripheral furrows to form the tetrads. $\times 1250$.
 Fig. 12. Microspores within the mother-cell wall, embedded in the mucilaginous coat. $\times 1250$.
 Fig. 13. Microspores, after mucilaginous coat has disappeared. $\times 1250$.
 Fig. 14. Pollen-grain, one-celled stage. $\times 1250$.
 Fig. 15. Same, division of the microspore nucleus. $\times 1250$.
 Fig. 16. Same, two-celled stage. $\times 1250$.
 Fig. 17. Same, shedding stage with elliptical generative cell. $\times 1250$.

PLATE II

- Fig. 18. Nucellar papilla with a large hypodermal archesporial cell. $\times 775$.
 Fig. 19. Linear tetrad of megaspores, surrounded by degenerating nucellar cells. $\times 775$.
 Fig. 20. Linear tetrad with functional (chalazal) megaspore enlarging. $\times 775$.
 Fig. 21. Functional megaspore dividing, three degenerating megaspores of which the sub-chalazal has already collapsed. $\times 775$.
 Fig. 22. Binucleate embryo-sac; of the three degenerating megaspores, the middle one is the last to degenerate. $\times 775$.
 Fig. 23. Four-nucleate embryo-sac with central vacuole. $\times 775$.
 Figs. 24, 25. The nuclei of the four-nucleate embryo-sac dividing to form 8 nuclei (adjacent sections of the same ovule). $\times 775$.
 Fig. 26. Mature embryo-sac with two synergids, one egg, three antipodals and two polar nuclei (not yet fused). $\times 775$.
 Fig. 27. Upper part of the embryo-sac showing the egg-apparatus and two polar nuclei. $\times 775$.
 Fig. 28. Same, with fusion nucleus. $\times 775$.
 Fig. 29. Elongated oospore; micropylar haustoria. $\times 775$.
 Figs. 30-32. Stages in development of embryo and suspensor with micropylar part of endosperm. $\times 775$.
 Fig. 33. Transverse section of the embryo surrounded by endosperm cells. $\times 400$.

PLATE III

- Fig. 34. Embryo-sac surrounded by nutritive jacket ; primary endosperm nucleus still undivided. $\times 400$.
- Fig. 35. Micropylar and chalazal endosperm chambers. Oospore in the resting condition. Some of the jacket cells binucleate. $\times 400$.
- Fig. 36. Chalazal haustorium binucleate ; micropylar chamber divided longitudinally and transversely, forming the micropylar haustorial cells and the middle cells. The oospore has elongated. $\times 400$.
- Figs. 37, 38. Chalazal haustorium divided obliquely (adjacent sections of the same ovule). $\times 400$.
- Figs. 39, 40. More advanced stage ; chalazal haustorium pouch-like ; embryo embedded in the endosperm (adjacent sections of the same ovule). $\times 380$.
- Fig. 41. Endosperm development by transverse wall formation in the middle cell ; chalazal haustorium binucleate. $\times 400$.

PLATE I

G. D. SRIVASTAVA - *Orobanchae aegyptiaca*

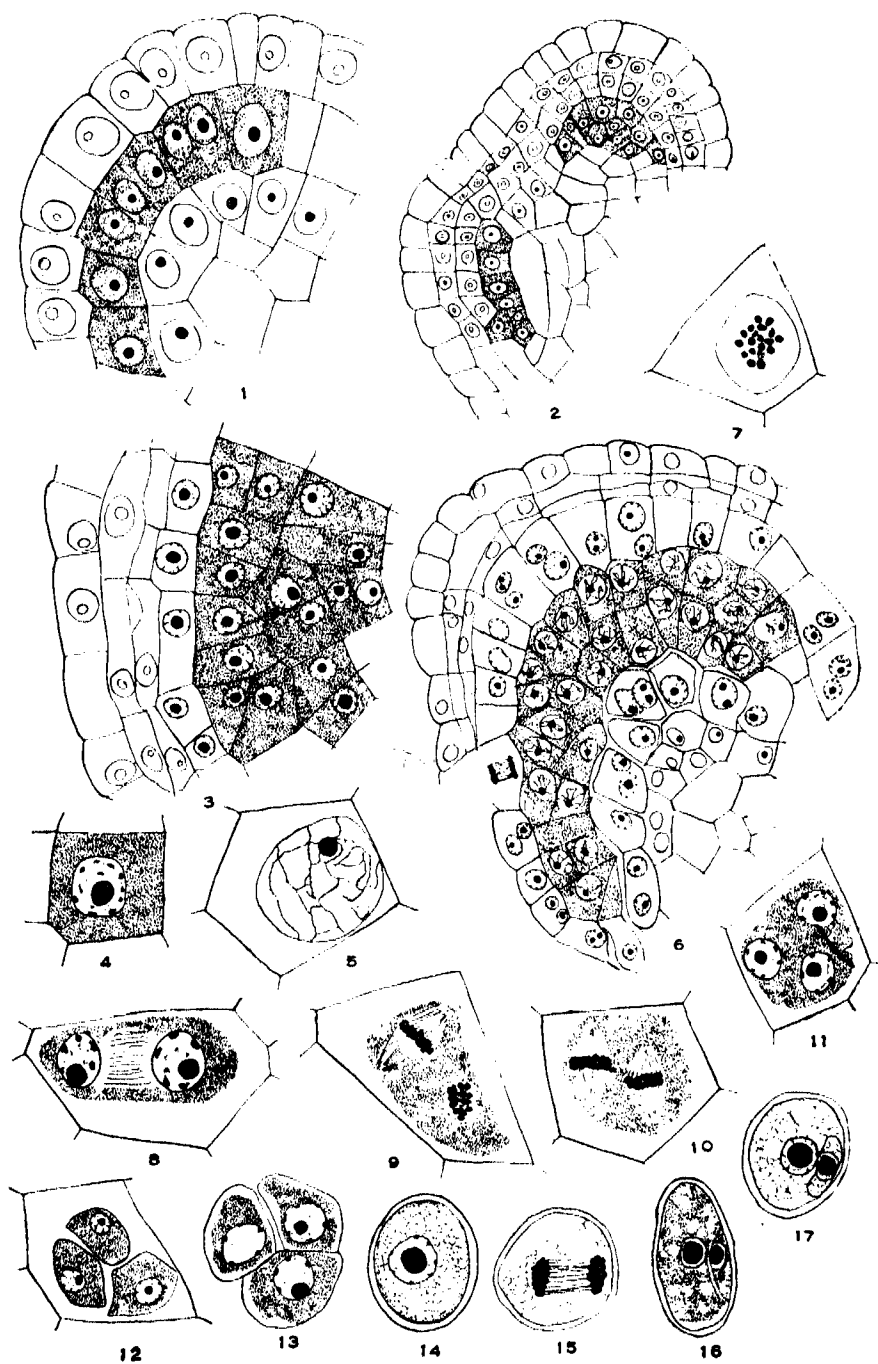


PLATE II

G. D. SRIVASTAVA -- *Orobanchae aegyptiaca*

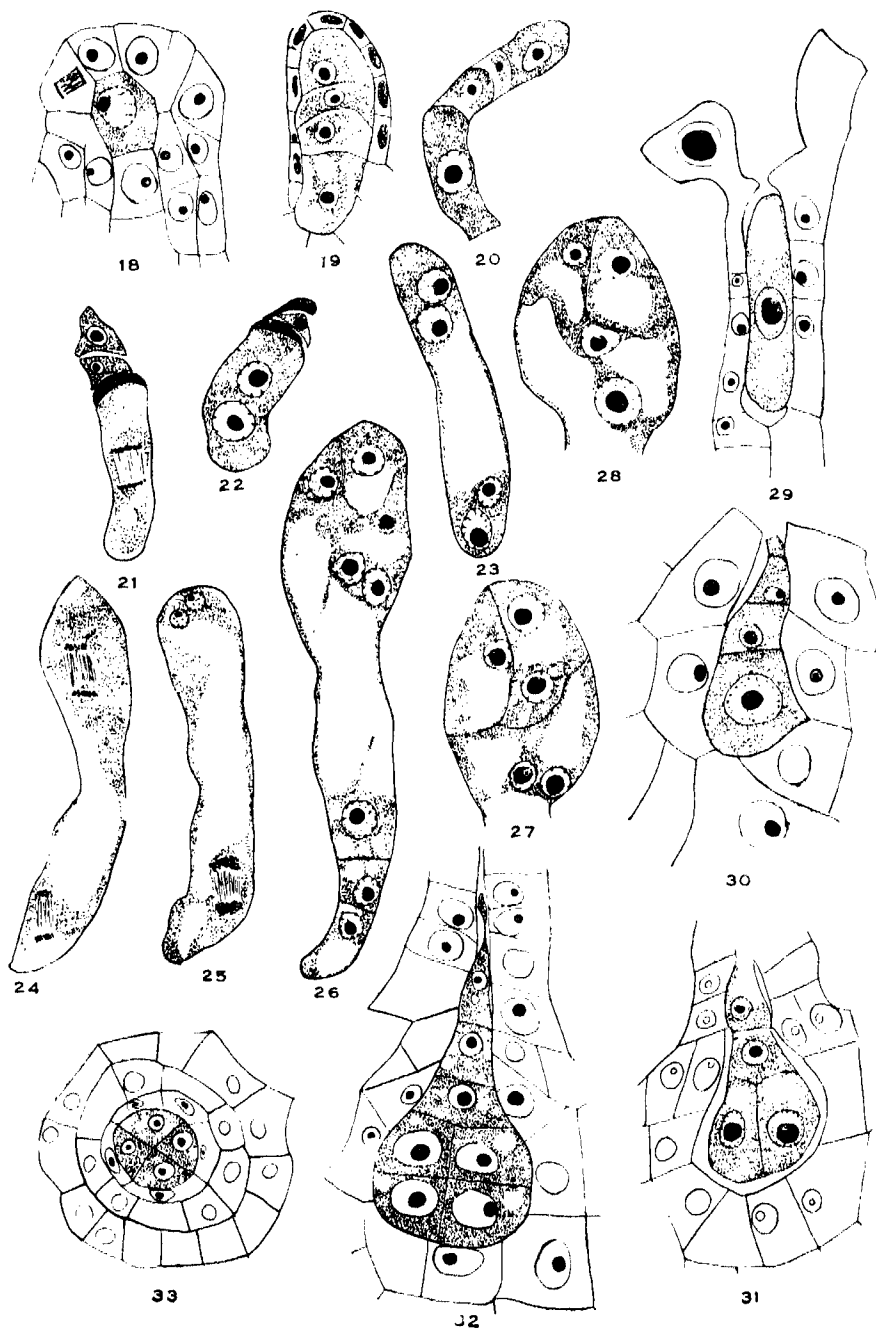
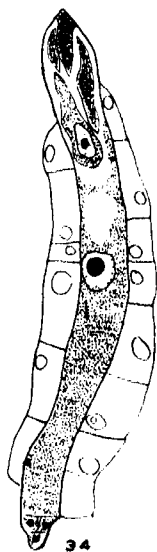
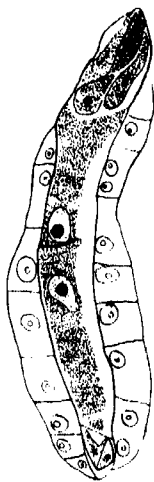


PLATE III

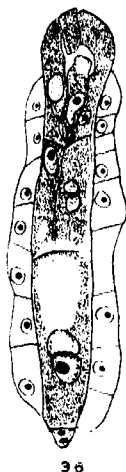
G. D. SRIVASTAVA-- *Orobanchae aegyptiaca*



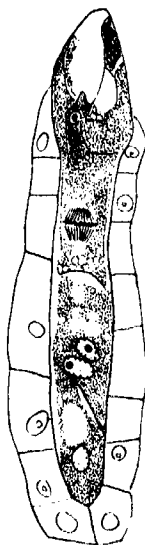
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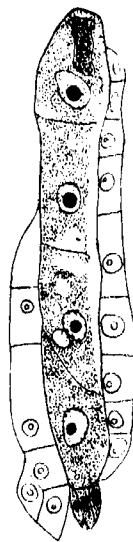
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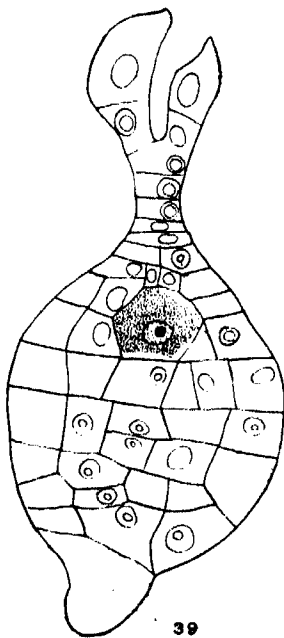
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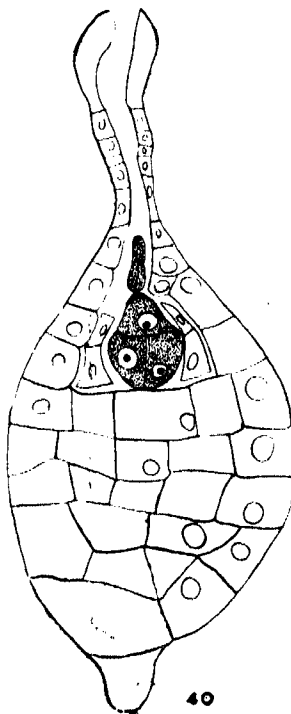
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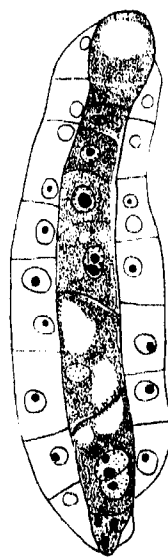
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COMPOSITION OF PATENT STILL MOLASSES FUSEL OIL OF INDIAN ORIGIN, PART II

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Received March 24, 1939

SUMMARY

Indian molasses fusel oil obtained from the Patent Still Distillery of Messrs Begg Sutherland and Co., Ltd., of Cawnpore, was exhaustively examined and fractionally distilled hundreds of times, whereby it was resolved into the following constituents: ethyl alcohol, isopropyl alcohol, n-propyl alcohol, water, acetal, ethyl isobutyrate, isobutyl alcohol, n-butyl alcohol, isoamyl alcohol, n-amyl alcohol, n-hexyl alcohol, n-heptyl alcohol, n-octyl alcohol, n-nonyl alcohol, furfural and a number of high-boiling esters of ethyl, isoamyl, n-amyl and n-octyl alcohols, in combinations with valeric, octylic, pelargonic, capric, lauric and myristic acids. The non-volatile residue obtained at the end of the distillation was found to be a wax consisting mainly of esters of palmitic, stearic and oleic acids with n-octyl alcohol. The solid greenish-brown substance obtained on allowing the fusel oil to stand for a week, was found to be a wax consisting of the ester of myricyl alcohol with some unknown high molecular weight, aliphatic monocarboxylic acid.

In a previous communication by the present author,¹ molasses fusel oil obtained from the Patent Still Distillery of Messrs Carew and Co., Ltd., of Rosa, Shahjehanpur, was submitted to fractional distillation with the help of fractionating columns and ultimately separated into constituents consisting of ethyl alcohol, isopropyl alcohol, n-propyl alcohol, isobutyl alcohol, acetal, water, ethyl isobutyrate, n-butyl alcohol, isoamyl alcohol, n-hexyl alcohol, n-heptyl alcohol, n-octyl alcohol, furfural and a solid crystalline hydrocarbon "melene." In the present instance, molasses fusel oil from a different source, namely, from the Patent Still Distillery of Messrs Begg Sutherland and Co., Ltd., of Cawnpore, was taken up for examination. Apparently due to different working conditions, the fusel oil from Cawnpore was found to be quite different from the fusel oil from Rosa, both from the physical as well as the chemical point of view. For, whereas the Rosa fusel oil was a pale cream-coloured opalescent liquid with a mild, characteristic, not unpleasant, alcoholic smell, and had a comparatively high specific gravity, Cawnpore fusel oil was a clear, brownish-yellow, lighter liquid, with a strong and somewhat nauseating smell of old whisky. Chemically also they were found to be quite different. Rosa fusel oil contains about 23 per cent of isopropyl and about 60 per cent of isoamyl alcohols, but Cawnpore fusel oil contains only about 2 per cent of isopropyl, but over 85 per cent of isoamyl alcohols. Rosa fusel oil does not contain any appreciable quantity of high-boiling esters, but Cawnpore fusel oil contains nearly 4 per cent of these interesting substances, which are apparently responsible for the strong characteristic

odour of the oil. Rosa fusel oil contains a crystalline hydrocarbon, but Cawnpore fusel oil contains a crystalline wax in its place.

From the commercial point of view, Cawnpore fusel oil should indeed be a more valuable substance, on account of the much larger proportion of isoamyl alcohol contained in it. With a suitable and comparatively cheap apparatus, the commercial recovery of isoamyl alcohol and whisky and rum essences from the Cawnpore fusel oil would indeed be a profitable proposition.

EXPERIMENTAL

Patent Still molasses fusel oil for the present investigation was obtained through the courtesy of Messrs Begg Sutherland and Co., Ltd., from their Cawnpore

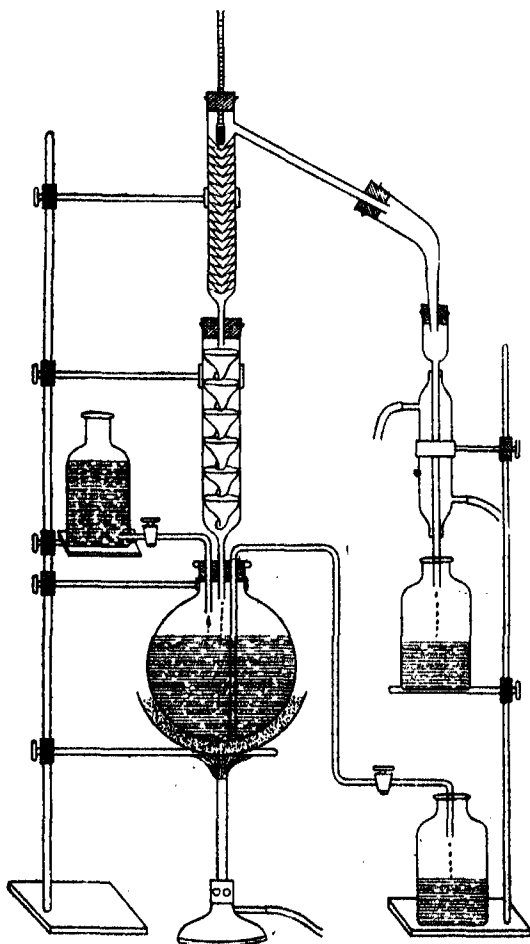


Fig. 1

Apparatus for the continuous distillation of fusel oil.

distillery, and was a clear brownish-yellow liquid with a strong characteristic odour resembling old whisky. The liquid had a specific gravity of 0.8532 at 22°C, and was weakly acidic in reaction. It deposited a very small quantity of a greenish-white waxy solid on being allowed to stand at the ordinary temperature (22°C) for about a week, and this has also been examined during the course of this investigation. Four gallons of this fusel oil, after decantation and filtration from the waxy deposit, was submitted to fractional distillation in a special apparatus set up for this purpose, consisting of a globular Pyrex boiling flask of one-litre capacity, fitted with two fractionating columns, one on top of the other, and with a device for the continuous or intermittent introduction or removal of liquid from the boiling apparatus, as shown in the diagram on page 70. The primary distillation was carried on in this apparatus in three stages, as shown in the following table :

Table I

Low-boiling fractions (Total quantity taken = 4 gallons = 17.448 c.c.)

Fraction No.	Boiling range	Quantity of distillate
1	80°-90°C	3835 c.c.
2	95°-127°C	450 c.c.
3	128°-131°C	12265 c.c.
4	Residue boiling above 131°C	803 c.c.
5	Experimental loss	95 c.c.
Total		17448 c.c.

Fraction No. 1 separated into two layers on standing. The upper layer No. 1A was oily and the lower layer No. 1B was aqueous. These were individually fractionated as shown in the following tables :

Table II

Fraction No. 1A (Total quantity = 2720 c.c.)

Fraction No.	Boiling range	Quantity of distillate
6	83°-90°C	40 c.c.
7	90°-95°C	26 c.c.
8	95°-99°C	30 c.c.
9	99°-100°C	100 c.c.
10	100°-128°C	345 c.c.
11	128°-131°C	2170 c.c.
12	Experimental loss	12 c.c.
Total		2720 c.c.

Table III

Fraction No. 1B. (Total quantity = 1115 c.c.)

Fraction No.	Boiling range	Quantity of distillate
13	83°-90°C	340 c.c.
14	90°-95°C	55 c.c.
15	95°-99°C	20 c.c.
16	99°-100°C	695 c.c.
17	Experimental loss	5 c.c.
Total ...		1115 c.c.

Fraction No. 1A + No. 1B = 2720 + 1115 = 3835 c.c. = Fraction No. 1.

Fractions Nos. 2 and 3 were then submitted to refractionation, using only the lower fractionating column of the distilling apparatus for this purpose. The results are given in the following tables :

Table IV

Fraction No. 2 (Total quantity = 450 c.c.)

Fraction No.	Boiling range	Quantity of distillate
18	90°-95°C	124 c.c.
19	95°-99°C	80 c.c.
20	99°-100°C	134 c.c.
21	100°-128°C	93 c.c.
22	128°-131°C	17 c.c.
23	Experimental loss	2 c.c.
Total ...		450 c.c.

Table V

Fraction No. 3. (Total quantity = 12265 c.c.)

Fraction No.	Boiling range	Quantity of distillate
24	120°-128°C	9 c.c.
25	128°-131°C	12252 c.c.
26	Residue boiling above 131°C	4 c.c.
Total ...		12265 c.c.

The various fractions given in the foregoing tables and having the same boiling range were united together, whereby the following collected fractions were obtained, as given in Table VI :

Table VI

Collected fractions

Fraction No.	Collection of fraction Nos.	Boiling range	Total quantity
27	6, 13	83°-90°C	380 c.c.
28	7, 14, 18	90°-95°C	205 c.c.
29	8, 15, 19	95°-99°C	130 c.c.
30	9, 16, 20	99°-100°C	929 c.c.
31	10, 21, 24	100°-128°C	447 c.c.
32	11, 22, 25	128°-131°C	14439 c.c.

These united fractions were then refractionated with the results shown in the following tables :

Table VII

Fraction No. 27 (Total quantity=380 c.c.)

Fraction No.	Boiling range	Quantity of distillate
33	80°-83°C	12 c.c.
34	83°-86°C	194 c.c.
35	86°-88°C	67 c.c.
36	Turbid residue	107 c.c.
Total ...		380 c.c.

Table VIII

Fraction No. 31. (Total quantity=447 c.c.)

Fraction No.	Boiling range	Quantity of distillate
37	90°-100°C (aqueous emulsion)	85 c.c.
38	100°-105°C	10 c.c.
39	105°-110°C	28 c.c.
40	110°-114°C	24 c.c.
41	114°-120°C	32 c.c.
42	128°-131°C	264 c.c.
43	Experimental loss	4 c.c.
Total ...		447 c.c.

Fractions Nos. 36 and 37 consisting of aqueous emulsions were united together and to this were added fractions Nos. 28 and 29 containing water soluble alcohols. The total quantity of (107 + 85 + 205 + 130) 527 c.c. was then submitted to refractionation as above. The results are given in the following table :

Table IX

Combined aqueous fractions (Total quantity = 527 c.c.)		
Fraction No.	Boiling range	Quantity of distillate
44	83°-86°C	160 c.c.
45	86°-88°C	12 c.c.
46	90°-95°C	1 c.c.
47	95°-99°C	46 c.c.
48	99°-100°C	60 c.c.
49	100°-105°C	14 c.c.
50	105°-110°C	16 c.c.
51	110°-114°C	8 c.c.
52	114°-120°C	39 c.c.
53	128°-131°C	169 c.c.
54	Experimental loss	2 c.c.

Total ... 527 c.c.

In the following table all the various low-boiling fractions distilling within the same boiling range have been brought together and their composition indicated after being confirmed by the preparation of suitable derivatives (cf. Dutt¹). In order to separate the constituents completely, hundreds of distillations were done although only about 75 are recorded in this paper.

Table X

Low-boiling fractions of fusel oil

Boiling range	Quantity	Composition	Correct b.p.	Percentage in fusel oil
80°-82°C	11 c.c.	ethyl alcohol	79°C	0'057
83°-88°C	433 c.c.	isopropyl alcohol	84°C	2'230
88°-95°C	2 c.c.	{ mixed isopropyl n-propyl alcohol	...	0'013
95°-99°C	46 c.c.	n-propyl alcohol	97°C	0'237
99°-100°C	1000 c.c.	water	100°C	5'150
100°-105°C	24 c.c.	acetal	104°C	0'124
105°-110°C	44 c.c.	isobutyl alcohol	108°C	0'227
110°-114°C	32 c.c.	ethyl isobutyrate	110°C	0'165
114°-120°C	71 c.c.	n-butyl alcohol	116°C	0'366
128°-131°C	14872 c.c.	isoamyl alcohol	129°C	85'230

The high-boiling fraction No. 4 was then taken up for re-fractionation, and this was done with the help of a short column, 8 inches in length, and in which four small bulbs had been blown. The results are indicated in Table XI.

Table XI

High-boiling fraction No. 4 (Total quantity = 803 c.c.)

Fraction No.	Boiling range	Quantity	Main composition	Correct b.p.	Percentage in No. 4.	Percentage in fusel oil
55	132°-140°C	18 c.c.	n-amyl alcohol	137°C	2.25	0.108
56	140°-150°C	6 c.c.	ethyl valerianate	145°C	0.75	0.033
57	150°-160°C	7 c.c.	n-hexyl alcohol	157°C	0.91	0.038
58	160°-170°C	3 c.c.	furfural	162°C	0.39	0.017
59	170°-180°C	4 c.c.	n-heptyl alcohol	174°C	0.52	0.022
60	180°-190°C	1 c.c.	unidentified	...	0.13	0.005
61	190°-200°C	4 c.c.	n-octyl alcohol	197°C	0.52	0.022
62	200°-210°C	9 c.c.	n-amyl n-valerate	205°C	1.17	0.050
63	210°-220°C	3 c.c.	n-nonyl alcohol	214°C	0.39	0.017
64	220°-230°C	12 c.c.	ethyl pelargonate	227°C	1.50	0.067
65	230°-240°C	3 c.c.	unidentified	...	0.39	0.017
66	240°-250°C	15 c.c.	isoamyl n-octylate	248°C	1.86	0.084
67	250°-260°C	18 c.c.	isoamyl pelargonate	259°C	2.25	0.100
68	260°-270°C	41 c.c.	n-amyl pelargonate	266°C	5.13	0.230
69	270°-280°C	118 c.c.	isoamyl caprate	278°C	14.515	0.660
70	280°-290°C	102 c.c.	n-amyl caprate	286°C	12.04	0.571
71	290°-300°C	166 c.c.	isoamyl laurate	298°C	19.75	0.930
72	300°-310°C	74 c.c.	n-amyl laurate	307°C	9.25	0.410
73	310°-320°C	27 c.c.	n-octyl laurate	319°C	3.27	0.147
74	320°-325°C	24 c.c.	n-octyl myristate	324°C	3.00	0.134
75	Waxy non-volatile residue = 140 c.c.			...	17.50	0.790
76	Experimental loss = 8 c.c.					

The main composition of the high-boiling esters of fusel oil from fractions No. 62 to No. 74 was found out by hydrolysis with strong (50%) aqueous caustic potash, and after the saponification was complete, by extraction of the liberated alcohol with ether. The free acid was then liberated by treatment of the mother liquor with dilute hydrochloric acid, and this was also extracted with ether. The acid as well as the alcohol thus obtained by the hydrolysis of the ester was then fractionated as usual and identified by formation of suitable derivatives (amides,

anilides and silver salts in the case of the acids, and p-nitrobenzoate, 3:5-dinitrobenzoate and acid phthalate in the case of alcohols). The results are given in Tables XII and XIV. It has been found that the saponification values of the esters are often considerably lower than the values expected from the main composition of the acid and alcohol obtained by hydrolysis, which indicates that not only the esters are mixtures of two or more isomeric substances or homologues, but there are hydrocarbons also mixed with them. This fact is borne out during the fractional distillation of the alcohols liberated by the hydrolysis of the esters. Along with the alcohols as the main constituents, a small quantity of a hydrocarbon is obtained in almost all the cases.

Table XII

High-boiling esters of fusel oil. Acids obtained by hydrolysis.

Fraction No.	Boiling range of acid	Neutralisation value of acid	Mean M. W. of acid	Name of acid	Correct M.W. of acid	Correct b.p.
62	185°-190°C	546	103.2	n-valeric	102	186.5°C
64	251°-257°C	350	160	pelargonic	158	254°C
66	230°-240°C	397	141	n-octylic	144	236°C
67	248°-257°C	363	154	pelargonic	158	254°C
68	248°-256°C	366	153	pelargonic	158	254°C
69	265°-275°C	320	175	capric	172	270°C
70	266°-275°C	325	172	capric	172	270°C
71	292°-305°C	291	192	lauric	200	300°C
72	296°-307°C	288	194	lauric	200	300°C
73	298°-309°C	281	199	lauric	200	300°C
74	310°-322°C	252	222	myristic	228	320°C

Table XIII

High-boiling esters of fusel oil. Alcohols obtained by hydrolysis.

Fraction No.	Boiling range of ester	Saponification value of ester	Boiling range of alcohol	Name of alcohol	Correct b.p.
62	200°-210°C	319	133°-140°C	n-amyl	137°C
64	220°-230°C	307	80°-82°C	ethyl	79°C
66	240°-250°C	264	127°-132°C	isoamyl	129°C
67	250°-260°C	241	127°-131°C	isoamyl	129°C
68	260°-270°C	243	133°-140°C	n-amyl	137°C
69	270°-280°C	228	127°-132°C	isoamyl	129°C
70	280°-290°C	226	133°-140°C	n-amyl	137°C
71	290°-300°C	224	130°-140°C	{ n-amyl isoamyl	...

Table XIII (contd.).

Fraction No.	Boiling range of ester	Saponification value of ester	Boiling range of alcohol	Name of alcohol	Correct b.p.
72	300°-310°C	212	133°-140°C 195°-203°C	n-amyl n-oetyl	137°C 198°C
73	310°-320°C	207	195°-203°C	n-oetyl	198°C
74	320°-325°C	199	195°-203°C	n-oetyl	198°C

Examination of the non-volatile waxy residue No. 75:— This was pitch-black in colour and on cooling became semi-solid of the consistency of vaseline. This was hydrolysed with 50 per cent aqueous caustic potash as usual and from the alkaline liquor, n-oetyl alcohol was recovered. The mother liquor on acidification gave a dark brown semi-solid acid mixture in which palmitic, stearic and oleic acids were detected.

Examination of the wax of fusel oil:— The greenish-grey solid (42 gms.) that separated out on allowing the fusel oil to stand for a week was collected by decantation and filtration, and on crystallisation from boiling alcohol, was obtained in the form of colourless leaflets (11 gms.) with a fatty lustre. The substance melted at 120°-121°C, and on hydrolysis with concentrated caustic potash yielded myricyl alcohol, m.p. 85°C. Thus the compound is an ester of myricyl alcohol with some unknown high molecular weight aliphatic acid. It burnt with a luminous flame and emitted the odour of burning candles. On account of the small quantity available, no further work on this interesting substance could be done. It is one of the very few high-melting waxes known, and if available in quantity, would indeed be a valuable substance from the technical point of view.

The author takes this opportunity of expressing his best thanks to Messrs Begg Sutherland and Co., Ltd, Cawnpore, for kindly sending him four gallons of fusel oil.

Reference

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CHEMICAL EXAMINATION OF THE SEEDS OF *MARTYNIA* *DIANDRA*. COMPOSITION OF THE FIXED OIL

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Received March 21, 1939

SUMMARY

1. The fixed oil from the seed of *Martynia diandra* was isolated by extraction with petroleum ether.
2. It is a pale yellow semi-drying oil.
3. On further examination it was resolved into the following constituents: palmitic acid, 8.08; stearic acid, 11.25; arachidic acid, 1.34; oleic acid, 35.84; linolic acid, 32.37; unsaponifiable matter (allyl alcohol), 2%, respectively.

Martynia diandra Gl. or Bichehu (Hindi) or Tiger's claw (English) is an American shrub (N. O. Pedalineeae) which has now become quite common in India on roadsides and waste places, growing during the rainy season and flowering and giving seeds during autumn. It is a coarse shrub of medium height, with large, opposite, cordate and glutinous leaves. The flowers are diandrous, white with patches of deep magenta and are handsome like those of *Sesamum indicum*. The fruit is about $1\frac{1}{2}$ inches in length, woody and beaked by two hard and curved spines, having the appearance of a large beetle. The fruit is highly medicinal. It is rubbed down with water and applied to the part stung by a scorpion, wasp or hornet. The Hindi name of the fruit has apparently been derived from this interesting property.

There appears to be practically no record of any work regarding the chemical composition of this drug except that the leaves contain chlorogenic acid ^{1, 2, 6}. Since the fruit still enjoys the reputation of being a very efficacious cure for scorpion bite, the present authors were led to put it to a thorough chemical examination. In the present investigation, an account of the chemical examination of the oil from the seed is given. The most important and interesting thing about the oil is that it yields a fairly high proportion of a liquid unsaponifiable matter, which has been identified to be allyl alcohol. The following fatty acids have been identified and estimated in the oil: stearic, palmitic, arachidic, oleic and linolic.

EXPERIMENTAL

Two kilos of the dry and crushed seeds were exhaustively extracted with petroleum ether in the cold, until the last extract yielded no oil and was perfectly colourless. In this manner, 207 grams of a greenish-yellow oil having a peculiar

odour were obtained (yield = 10.35%). The oil was then purified with animal charcoal and Fuller's earth and obtained as a perfectly transparent and pale yellow liquid. The oil, even on prolonged standing, did not deposit any sediment or crystalline matter.

Examination of the oil—The oil contains no nitrogen or sulphur and is optically inactive. It burns with a luminous and slightly sooty flame. On further examination it was found to belong to the class of semi-drying oils. Table I contains the usual physical and chemical properties of the oil.

Table I

Specific gravity at 25°C	0.9178
Refractive index at 26°C	1.4636
Solidifying point	-13°C
Acid value	4.9
Saponification value	198.4
Iodine value	118
Hehner value	89
Acetyl value	31.4
Unsaponifiable matter	2.0%

145 grams of the oil was saponified as usual with alcoholic caustic potash, and the soap, formed after the complete removal of alcohol and drying, was extracted with ether in order to remove the unsaponifiable matter. The residue was then dissolved in sufficient amount of warm water and decomposed with dilute sulphuric acid in presence of petroleum ether. The petroleum ether solution of the fatty acids thus liberated was washed free from traces of sulphuric acid by distilled water, dried, and the solvent removed by distillation, when the mixed fatty acids were obtained as a viscous, semi-solid mass. Table II gives constants of the mixed fatty acids.

Table II

Specific gravity at 25°C	0.9412
Neutralisation value	198.65
Mean molecular weight	282.4
Iodine value	122.8

The mixed fatty acids were then separated into saturated (solid) and unsaturated (liquid) acids by Twitchell's⁵ lead salt-alcohol method and Table III gives the percentages, iodine values and mean molecular weights of the saturated and unsaturated acids.

Table III

Acids	Percentage in mixed acids	Percentage in the oil	Iodine value	Mean molecular weight
Saturated	24.67	21.95	175	275.6
Unsaturated	75.33	66.83	132.4	280.5

Examination of the unsaturated acids :—The unsaturated acids separated by the above method were further examined and their constituents determined quantitatively by the method of Jameison and Boughmann,³ by preparing their bromine addition products. The hexabromo derivative of linolenic acid is insoluble in cold ether. Since no precipitate insoluble in ether was formed, so the absence of linolenic acid was confirmed. The ether soluble portion was dissolved in petroleum ether (b. p. 40°-60°C) and cooled in a refrigerator, when crystals of linolic tetrabromide (m. p. 113°C) separated out from the solution, showing thereby the presence of linolic acid. The filtrate was evaporated to dryness and the bromine content estimated. Table IV contains the results of analysis of the bromine addition products.

Table IV

Weight of the unsaturated acid taken	5.5762 gm.
Linolic tetrabromide	2.8246 gm.
Residue (filtrate evaporated to dryness)	7.3998 gm.
Bromine content of the residue	42.47% gm.
Oleic dibromide in residue	4.6862 gm. (63.33%)
Linolic tetrabromide in residue	2.7136 gm. (36.67%)
Total tetrabromide formed	5.5382 gm.
Linolic acid equivalent of tetrabromide	2.6364 gm. (47.46%)
Oleic acid equivalent of dibromide	2.9398 gm. (52.54%)

The proportions of linolic and oleic acids were also determined from the iodine value of the liquid fatty acids and the proportions, calculated in this way, were found to be almost identical with the proportions determined from the bromine addition products.

Examination of the saturated acids :—The saturated acids obtained by the lead salt-alcohol method were freed from traces of liquid fatty acids by pressing on a porous plate. The acids thus obtained were perfectly dry, solid, almost white in appearance and melted between 52°-56°C.

The mixed acids were converted into their methyl esters by dissolving them in pure methyl alcohol and passing a current of dry hydrogen chloride to saturation. The esterification was completed by heating the product on a water-bath under

reflux for about eighteen hours. The methyl esters thus formed were neutralised with sodium bicarbonate, washed with distilled water and extracted with ether. After drying and removal of the solvent, the mixed methyl esters were separated into a number of fractions by distillation under reduced pressure at different boiling ranges. The iodine values and saponification values of the different fractions were determined and the mean molecular weights were calculated. Table V contains the results thus obtained.

Table V

(Fractional distillation of methyl esters at 4.5 mm.)

Fraction No.	Boiling range	Quantity	I. V.	Mean M.W.	Sap. V.	Unsaturated acid %
1	151-155°C	1.81 gm.	1.13	276.76	202.7	0.89
2	163-166°C	3.49 gm.	1.65	282.9	198.3	1.27
3	170-173°C	3.37 gm.	2.25	285.60	196.4	1.77
4	178-186°C	2.70 gm.	3.56	291.40	192.5	2.80
5	186-195°C	2.20 gm.	19.10	294.00	190.8	15.10
6	above 195°C	1.82 gm.	..	...	...	...

Table VI

Fraction No.	Palmitic acid		Stearic acid		Arachidic acid	
	%	gm.	%	gm.	%	gm.
1	77.51	1.40	22.49	0.394	...	...
2	55.51	1.920	44.49	1.516	...	...
3	45.98	1.522	54.02	1.788	...	...
4	23.13	0.607	76.87	1.918	...	...
5	11.74	0.220	88.26	1.650	...	...
6	...	...	34.00	0.521	66.00	1.01

Table VII

Acid	Percentage in saturated acids	Percentage in the purified oil	Percentage in the original oil
Palmitic	36.82	9.08	8.08
Stearic	51.30	12.65	11.25
Arachidic	6.56	1.51	1.34
Unsaturated (solid)	5.32	1.31	1.16

Examination of the unsaponifiable matter :—The unsaponifiable matter obtained by ether extraction of the soap was repeatedly washed in ethereal solution with water. After drying, the ether was evaporated when a pale yellow liquid was obtained. The product was again treated with alcoholic caustic potash in order to make sure that no unchanged oil was left behind, and the unsaponifiable matter isolated as before. It was thus definitely ascertained that the unsaponifiable matter is a liquid. On further examination it was found to be an alcohol boiling at 97°C. The odour was penetrating and mustard-like. The liquid was found to be *miscible* with water and unsaturated. The substance was identified to be allyl alcohol by specific reactions of the substance given by Mulliken.⁴

One of the authors (J. N. T.) wishes to express his indebtedness to the Kanta Prasad Trust of the Allahabad University for a Research Scholarship, which enabled him to participate in this investigation.

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CONSTITUTION OF SANTALIN

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SUMMARY

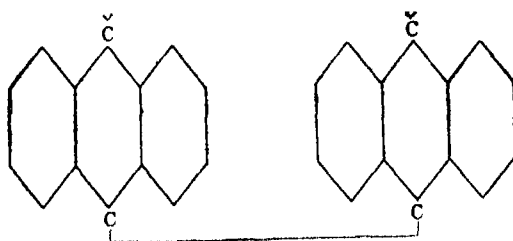
The constitution of santalin has been discussed in the light of work that has already been done and a new formula for santalin has been proposed containing a double flavylum structure with a tetrahydroxy benzene nucleus in the molecular configuration. The new formula agrees much better with the known chemical properties of santalin than any proposed before.

The heart wood of *Pterocarpus santalinus* Linn. has long been famous for its red colouring matter, which has been the subject of investigation by a number of chemists^{1, 11, 16, 17, 22, 32, 33} ever since 1832 when Pelletier^{19, 20} for the first time attempted its isolation. Cain and Simonsen⁴ succeeded in preparing santalin in a fairly pure state as a bright red microcrystalline powder which softened at 223°C and melted at 226°C. These authors on the basis of their elementary analysis and molecular weight in phenol assigned to santalin the formula $C_{15}H_{11}O_5$ which could be further expressed as $C_{11}H_9O_2(OCH_3)(OH)_2$ since it afforded diacetyl-, nitro-diacetyl-, and dibenzoyl-santalin and on reductive acetylation with acetic anhydride, sodium acetate and zinc dust gave a compound $C_{21}H_{20}O_8$ or $C_{14}H_8O.(OCH_3)(O.COCH_3)_3$ which appeared to contain three acetyl groups. By using methyl sulphate and alkali as methylating agent these authors obtained santalin-monomethyl-ether and santalin-dimethyl-ether.

Cain, Simonsen and Smith⁵ during the course of their investigation made the following important observations that (a) molecular formula for santalin is $C_{30}H_{28}O_{10}$ on the ground of molecular weight determination of santalin-tetra-methyl-ether, santalin-dimethyl-ether and tetra-acetyl santalin by Barger's drop method; (b) santalin-tetra-methyl-ether $C_{34}H_{36}O_{10}$ as well as santalin-dimethyl-ether $C_{32}H_{32}O_{10}$ on oxidation with potassium permanganate yield anisic and veratric acids; (c) both tetra-methyl and dimethyl-santalin undergo reductive acetylation in which one ketonic group is reduced and subsequently acetylated.

Since however santalin is a polyhydric phenol, the evidence of its molecular weight cannot be accepted without reserve while since two of the derivatives employed by these authors contain no free hydroxy group, their molecular weight is

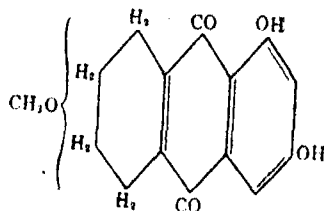
unlikely to be influenced by association or dissociation. These authors mention in their paper the isolation of anthracene by Grandmougin during zinc dust distillation experiments with santalin and though they themselves were unable to confirm this beyond doubt they were of the opinion that its skeleton formula is that of a dian-



thracene derivative and this in spite of the difficulty encountered in accounting for the remaining hydrogen atoms.

Later on O'Neill and Perkin¹⁸ obtained santalin as a chocolate coloured powder which did not possess a distinct melting-point but softened at 243°C and decomposed at 250°C—260°C. They assigned the formula $C_{24}H_{22}O_8$ to santalin which afforded a tetra-acetyl derivative $C_{24}H_{18}O_8(COCH_3)_4$ as deep salmon coloured powder decomposing above 225°C. They also made the important observation that santalin shows evidence of formation of soluble oxonium salts with mineral acids but the significance of this observation was lost sight of by next subsequent workers.

Recently Dieterle and Stegmann⁹ obtained santalin as a red microcrystalline powder which began to soften at 268°C and carbonize above 300°C. As a result of their investigation they assigned to santalin the molecular formula $C_{14}H_9O_2(OCH_3)(OH)_2$ and the following constitutional formula having an anthraquinone structure with a reduced benzene nucleus, but the position of methoxy group being still uncertain. The products obtained by Dieterle and Stegmann during many of the



reactions they studied can be traced to the presence of a small quantity of homopterocarpin and pterocarpin the colourless companions of santalin and which are difficult to be removed unless purification of santalin is effected through its oxonium salt. The reported formation of anthraquinone by oxidation with chromic acid of the product obtained during zinc dust distillation, of anthracene during the reduction of santalin with red phosphorus and hydriodic acid, of styphnic acid by oxidation

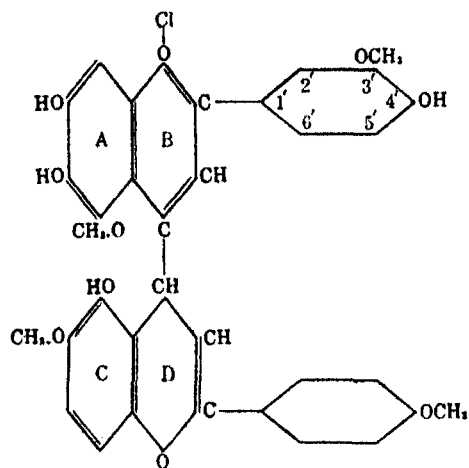
with concentrated nitric acid in glacial acetic acid solution as well as the formation of homopterocarpin^{21, 23} which has the formula $C_{17}H_{16}O_4$, by oxidation with $K_2Fe(CN)_6$ is really due to the colourless impurities for homopterocarpin^{10, 15, 23} is known to yield methyl-anthracene m.p. $167^\circ C$ and resorcinol-dimethyl-ether on zinc dust distillation and styphnic acid as one of the products on oxidation with nitric acid. It is utterly impossible to conceive how homopterocarpin could ever be obtained from santalin and the only conclusion is that their sample of santalin was impure (vide Raudnitz.²⁴) On the other hand these impurities remained intact during the reactions studied by Cain, Simonsen and Smith, for homopterocarpin and pterocarpin are resistant towards permanganate oxidation (vide Dieterle and Leonhardt¹⁰) and consequently their isolation of anisic and veratric acids as the main product of oxidation of santalin-dimethyl-ether and santalin-tetramethyl-ether derives special importance and significance.

In 1934 Raudnitz, Navratil and Benda²³ for the first time obtained santalin in the form of well-defined crystals and in a pure state free from colourless impurities, while the previous investigators only carried out experiments with slightly impure samples^{13, 14, 24}. These authors obtained santalin hydrochloride as splendid metallic green iridescent needles with reddish brown streak and the sample dried to constant weight at room temperature in high vacuum over phosphorus pentoxide had the composition agreeing with the formula $C_{34}H_{29}O_6Cl$ which could be further resolved into $C_{30}H_{17}O_6Cl(OCH_3)_4$. Similarly the elementary analysis and Zeisel's experiment with santalin, easily obtained by decomposition of its hydrochloride with boiling water led to its being assigned the formula $C_{30}H_{16}O_6(OCH_3)_4$. These investigators noted that santalin hydrochloride loses hydrogen chloride on drying in high vacuum at $100^\circ C$ and that in its general behaviour, reaction with dilute alkalis, and reaction with ferric chloride resembles anthocyanin and anthocyanidins. This view is also confirmed when we find that santalin hydrochloride solutions are decolorized on catalytic hydrogenation with platinum oxide and also by heating with sodium hydrosulphite solutions.

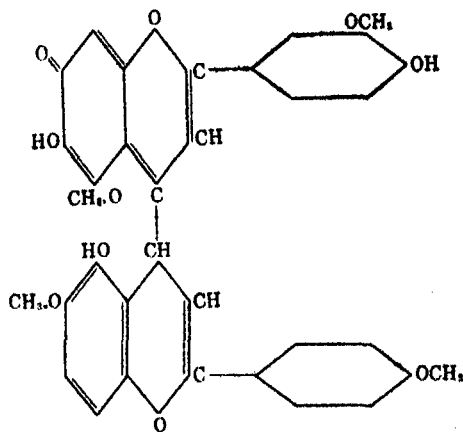
The structural formulae for santalin have been proposed by a number of investigators but now in view of the fact that santalin resembles anthocyanidins the present author has attempted to arrive at a satisfactory formula for the substance.

The composition of santalin, the fact that santalin and santalin hydrochloride can be easily transformed one into the other without isomerization, and the absence of formation of dibasic acids from among the degradation products of santalin derivatives, at once point out that it is not allied to naturally occurring dihydropyran derivatives such as hæmatein and brazelein but that it is really an anhydrobase of a pyrylium salt, and is allied to carajurin $C_{17}H_{14}O_6$ which was investigated by Perkin²¹ and later on by Chapman, Perkin and Robinson.⁷ The analogy existing between santalin, carajurin from *Bignonia chica* and the hydroxy-benzopyranol

bases^{9, 12} is indeed striking. On the assumption that the salts of santalin are flavylum derivatives it is of great significance to note that these exhibit no tendency to pass into pseudobase. Since the effect of a hydroxy or methoxy group in position 3 in the pyrylium nucleus in facilitating pseudobase formation is well established by the work of Robinson,^{29, 30} it is concluded that santalin is related to flavone rather than to the flavanol group and bearing in mind, the formation of anisic and veratric acids as the only recognizable product, obtained by permanganate oxidation of methylated santalin, the following structural formulæ (I and II) are proposed for



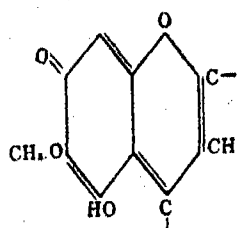
I



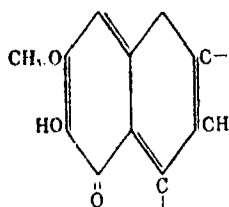
II

santalin hydrochloride and santalin respectively. Such a constitutional formula containing a tetrahydroxy-benzene nucleus A serves to explain the absence of other recognisable products during permanganate oxidation. As regards the arrangement of the substituents in the benzene nucleus A of formula I, X and Y are tautomeric and would yield identical hydrochloride Z. For reasons which applied in the case of carajurin either of these formulæ X and Y will be untenable since the resulting hydrochloride Z would not give any ferric chloride reaction due to the absence of vicinal hydroxy groups while santalin hydrochloride gives violet coloration with ferric chloride. The choice between M and N cannot be made definitely, but (N) is preferable on account of the colour and stability of santalin for whereas M should be a violet or blue substance and unstable because anhydrobases⁶ from 5-hydroxy-flavylum salts are violet or blue and characterized by their instability while anhydrobases from 7-hydroxyflavylum salts are red.

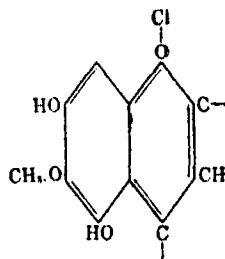
The reddish violet coloration which santalin hydrochloride gives with dilute alkalis definitely points to the presence of a free hydroxyl group in the 4' position.^{3, 8} It is interesting to note that in its reaction with dilute alkalis santalin



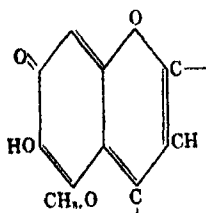
X



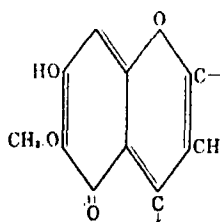
Y



Z

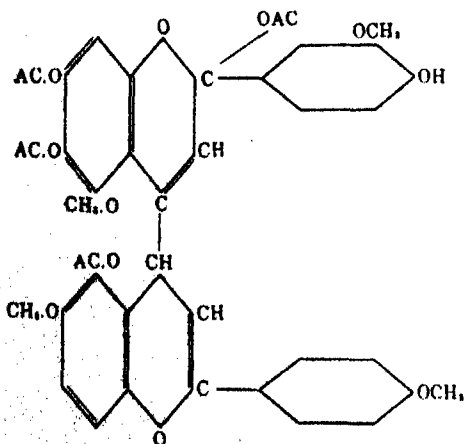


M

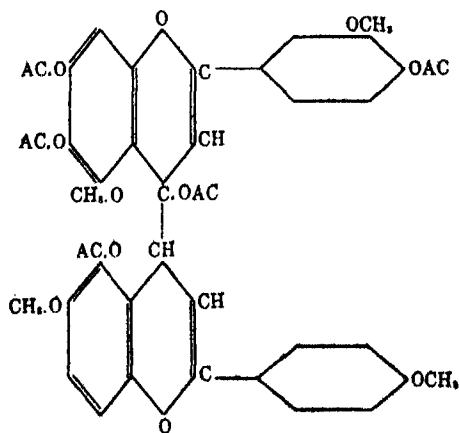


N

hydrochloride very much resembles callistephin chloride^{24, 27, 28}, $C_{21}H_{21}O_{10}Cl$ which is now known to be 3- β -glucosidyl-perlargonidin-chloride in view of the generalization^{27, 28} arrived at by Robinson that the position 5' is of little value in the alkali reaction provided that position 7 is hydroxylated. Santalin having the formula II would be expected to give on acetylation with acetic anhydride and pyridine a o-penta-acetyl-dihydrosantalinol having the formula III or IV and this is also borne by the



III



IV

observations of Perkin¹¹ (cf. Carajurin and Carajuretin). As regards the second half of the molecule it is very similar to the first half and contains the γ -pyran nucleus but the oxygen atom present in the ring though capable of forming oxonium

salts with concentrated mineral acids just as the natural flavones and flavonols do and in common with the γ -pyrone and γ -pyran derivatives but of the type quite unlike those afforded by the anhydroflavylium bases. The second oxygen atom present in the ring D is incapable of affording stable oxonium salts with 2 per cent methyl or ethyl alcoholic hydrochloric acid.

It is hoped that further experimental investigation on santalin will confirm the formula assigned by the present author.

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MIGRATION OF PARA HALOGEN ATOM IN A DERIVATIVE OF META-CRESOL

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SUMMARY

1. Pure 4-bromo 3-Methylphenol has been synthesised from metatoluidine.
2. The action of concentrated nitric acid on 4-bromo 3-methylphenol has been studied, and it has been established that during nitration the bromine atom migrates to position 2.
3. The constitution of the dinitro-bromocresol obtained by the nitration of 4-bromo 3-methylphenol, has been established to be 2-bromo 4 : 6 dinitro 3-methylphenol.

It has frequently been observed, that during nitration of a halogenated phenol, migration of the para halogen atom often takes place, even under the mildest conditions of nitration.^{5, 6, 7} An instance of migration of the bromine atom has been observed when 4-bromo 3-methylphenol is nitrated, which is described below.

Walther and Demmelmeyer⁸ nitrated a bromocresol, which they had obtained by the bromination of meta-cresol in carbontetrachloride solution at -5°C ¹⁰ and to which they assigned the constitution 4-bromo 3-methylphenol ($\text{OH}=1$), and obtained a mononitro and a dinitro compound melting at 124°C and 111°C respectively. To these compounds they assigned the constitutions 6-nitro 4-bromo 3-methylphenol and 2 : 6 dinitro 4-bromo 3-methylphenol respectively.

A dinitro bromocresol of the above constitution has been prepared by Gibbs and Robertson¹ and also by Raiford and Leavel.⁴ Gibbs and Robertson obtained it by the nitration of 6-nitro 4-bromo 3-methylphenol in acetic acid solution, which itself was obtained by the bromination of 6-nitro 3-methylphenol; but the melting-point of the dinitro compound obtained by them is 78°C .

Raiford and Leavel nitrated the same bromo-nitrocresol (m. p. 124°C), in the presence of concentrated sulphuric acid and obtained a dinitro compound having the melting-point 78°C .

It will be seen from the above, that the same substance has been assigned two different melting-points by different authors and this led us to investigate into the constitutions of these two dinitro-bromocresols.

We repeated the work of Walther and Demmelmeyer and found that the melting-point of their dinitro-bromo-metacresol on recrystallisation from toluene, rises to 115°C . This is also the melting-point of 2-bromo 3-methyl 4:6 dinitro phenol ($\text{OH}=1$), prepared by Sane and Joshi.⁶ The constitution of this dinitro-bromo-cresol prepared by these authors has been established by them beyond doubt. Further in order to establish the identity of these two dinitro-bromocresols, we prepared four derivatives from the dinitro-bromo-metacresol, prepared according to Walther and Demmelmeyer's method, and these compounds were found to have the melting-points :—toluene-sulphonyl ester, m. p. 141°C , chloro derivative m. p. 81°C , amino derivative m. p. 208°C and diphenylamine compound m. p. 130°C and are therefore identical with those obtained by Joshi⁸ from 2-bromo 3-methyl 4:6 dinitrophenol.

There is no doubt that the bromo-metacresol from which Walther and Demmelmeyer obtained the mononitro and dinitro-bromo-metacresol has the constitution 4-bromo 3-methylphenol as it was found to be identical with the para bromocresol obtained by Darzens and Levy, who have established its constitution as 4-bromo 3-methylphenol. We prepared 4-bromo 3-methylphenol by Darzens and Levy's method and found that the mono and dinitro bromo-metacresols obtained from it has the same melting-points, *viz.*, 124°C and 115°C respectively. Various other derivatives, mentioned above were prepared and were found to be identical with the corresponding derivatives prepared from Walther and Demmelmeyer's dinitro-bromo-metacresol.

The constitution of this bromo-metacresol was further confirmed by synthesising it from meta-toluidine. This was acetylated, brominated, and after saponification, the NH_2 group was replaced by OH . The compound so obtained is 4-bromo 3-methylphenol. This was found to be identical with bromo-metacresol of Walther and Demmelmeyer and also yielded a dinitro-bromo compound having the melting-point 115°C . There is therefore no doubt that during nitration of 4-bromo 3-methylphenol the bromine atom migrates from position 4 to position 2, and the constitution of the bromo-metacresol described by Walther and Demmelmeyer is 2-bromo 3-methyl 4:6 dinitrophenol ($\text{OH}=1$).

EXPERIMENTAL

4-bromo 3-methylphenol.—This substance was prepared according to the methods of Walther and Zipper, Darzens and Levy² and also from 4-bromo 3-methylaniline.¹¹ By following the method of Walther and Zipper no crystals of the bromo-cresol could be obtained by simply cooling the final product, hence it was distilled under reduced pressure, when the distillate was found to solidify in the receiver, m. p. 62°C .

Synthesis from 4-bromo 3-methylaniline:—The bromo-metatoluidine was dissolved in 10 times its weight of HCl, cooled to 0°C and then the calculated quantity of sodium nitrite was added in small portions. The solution was allowed to stand for half an hour and then the diazo solution was decomposed by boiling and the bromocresol formed was separated by steam distillation. By all these methods the same compound in fine needles, m. p. 62°C, was obtained.

2-bromo 4, 6 dinitro 3-methylphenol:—Each of the above bromo-metacresols on nitration gave this compound, m. p. 115°C. The nitration was carried out by dissolving the bromocresol in an equal weight of acetic acid and then adding to it, drop by drop, an excess of nitric acid (density 1.4), under constant stirring. The dinitro compound separated out on addition of a little ice water. This was filtered and recrystallised from alcohol twice and once more with toluene; the melting-point of the substance so obtained is 115°C.

Toluene sulphonyl ester of 4, 6 dinitro 2-bromo 3-methylphenol:—This substance was obtained in the usual way by the condensation of 4, 6 dinitro 2-bromo 3-methylphenol, and paratoluene-sulphonyl chloride in the presence of sodium carbonate. Melting-point of the ester so obtained is 141°C. (Found sulphur, 7.5%, 7.3%: required sulphur, 7.4%).

1-chloro 2-bromo 3-methyl 4, 6 dinitrobenzene:—A mixture of 2-bromo 4, 6 dinitro 3-methylphenol 3 gm., para-toluene-sulphonyl chloride 2 gm., and diethylaniline 10 c.c., were heated on the water bath for 4 hours. The mixture was then cooled, acidified with hydrochloric acid, washed with water, and finally recrystallised from alcohol, m. p. 81°C. (Found nitrogen, 9.1%: required nitrogen, 9.4%; Cl + Br, 38.8%: required Cl + Br, 39.01%).

2-bromo 4, 6 dinitro 3-methyl 1-phenylamine:—The diphenylamine compound was obtained in the usual way by heating the requisite quantities of the chloro compound, aniline, absolute alcohol and fused anhydrous sodium acetate on a water bath for half an hour and then isolating in the usual way, m. p. 130°C. (Found nitrogen, 11.9%: required nitrogen, 11.93%).

Further work in this connection is being carried out in this laboratory and will be discussed in detail in a subsequent paper.

My thanks are specially due to the Lucknow University for the award of a fellowship and to Dr. S. M. Sane for help and guidance during the course of the work.

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COLOUR IN RELATION TO CHEMICAL CONSTITUTION OF THE ORGANIC AND INORGANIC SALTS OF ISONITROSO-MALONYL-GUANIDINE

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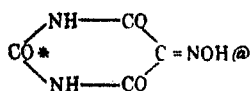
Received March 25, 1939

SUMMARY

Isonitroso-malonyl-guanidine has been prepared in a perfectly pure and crystalline condition for the first time by a new method, and its organic and inorganic salts prepared. The acid has been found to be very weak in character and to combine only with comparatively strong organic and inorganic bases with formation of salts. The acid as well as the salts have very similar, and in fact almost identical absorption bands, and this is quite contrary to the behaviour of violuric and thiovioluric acids with which isonitroso-malonyl-guanidine is structurally very closely related. From this the conclusion is drawn that isonitroso-malonyl-guanidine is differently constituted from the other two compounds, and new structures for this compound in the free state and in the form of its salts have been proposed from theoretical considerations, particularly in view of a "Theory of colour on the basis of molecular strain" advanced by Dutt.

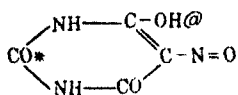
The effect of substitution of an oxygen atom in violuric acid by a nitrogen atom has been compared and it has been found that the effect is very similar to the substitution by a sulphur atom

Isonitroso-malonyl-urea or violuric acid which forms interesting magenta coloured salts with organic and inorganic bases, and dissolves in water to a pale pink solution, has been the subject of intensive study by Ghatak and Dutt,³ who from the absorption spectra of these compounds came to the conclusion, that although the structure of violuric acid itself is the comparatively less strained configuration (I), yet the process of salt formation produces the highly strained structure (II) by the migration of a hydrogen atom (@):



(I)

Violuric acid (Oximinoketonic form)



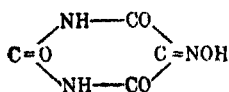
(II)

Violuric acid (Nitroso-enolic form)

A similar behaviour was observed by Lal and Dutt³ in the case of thiovioluric acid in which the oxygen atom in violuric acid marked with an asterisk has been replaced by a sulphur atom. The replacement of oxygen by sulphur increases the

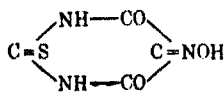
load in the vicinity of the strained part ($C=O$) of the molecule, and consequently the salts of thiovioluric acid are found to be much deeper in colour than the corresponding salts of violuric acid, *i.e.*, violet instead of pink.

Isonitroso-malonyl-guanidine, which is structurally very closely related to violuric acid and thiovioluric acid (as can be seen from the following constitutions of these compounds) and which differs from the other two by



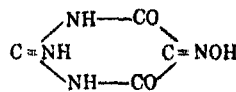
(III)

Violuric acid



(IV)

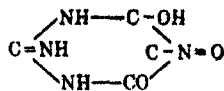
Thiovioluric acid



(V)

Isonitroso-malonyl
guanidine

possessing the $=\text{NH}$ group instead of the divalent oxygen or sulphur atom, has been found to yield intensely coloured salts with organic and inorganic bases which exhibit violet colour in aqueous solution with an absorption maxima in the neighbourhood of 5800\AA . It is the aim of the present investigation to exhaustively study this interesting compound from this point of view, and find out how far its behaviour is comparable to that of violuric acid and thiovioluric acid. The chief marked difference observed between the present series of compounds and the other two is that, whereas in the latter two cases the acids in aqueous solution are weakly coloured but yield highly coloured salts, in the former case the colour of the acid itself is practically as intense as that of the salts. If from the point of view of analogy with violuric and thiovioluric acids, we take the structure of isonitroso-malonyl-guanidine to be (V), then salt formation should invariably result in conversion of this form into the more strained nitrosoenolic configuration (VI) shown below, accompanied by the deepening of colour.

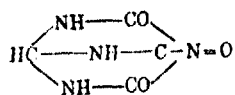


(VI)

Isonitroso-malonyl-guanidine
(Nitroso-enolic form)

But since no deepening of colour takes place by salt formation, it is obvious that (V) could not be the correct representation of isonitroso-malonyl-guanidine. This abnormal behaviour of the compound and its salts can only be explained by the assumption that both the acid and its salts possess the same or nearly the same configuration with the highly strained $\text{N}=\text{O}$ present in each of them. Structure (VI)

can be considered to be one of the possibilities, and the only other alternative is represented below (VII):

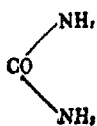


(VII)

Isonitroso-malonyl-guanidine

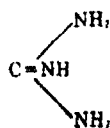
That free isonitroso-malonyl-guanidine possesses the structure (VI) is very unlikely, since in that case there is no reason why such a strained configuration should not tautomerise into a comparatively much less strained variety represented by (V), particularly in view of the fact that in the free acid, there is no influencing factor like salt formation that would fix the labile hydrogen atom after tautomerisation into the nitroso-enolic structure (VI).

Now the most satisfactory structure for isonitroso-malonyl-guanidine is (VII), which although somewhat difficult of conception, is nevertheless supported by the following considerations: (a) urea is a neutral compound, but guanidine is strongly basic, and on comparing the structures of the two substances, it becomes obvious that the basic character has been imparted to the guanidine molecule by the =NH group present, since in all other respects they are identical as shown below;



(VIII)

Urea

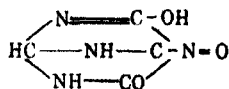


(IX)

Guanidine

(b) Isonitroso-malonyl-guanidine when compared to isonitroso-malonyl-urea or violuric acid, is found to be much less acidic than the latter. Obviously the cause of the weakly acidic nature of isonitroso-malonyl-guanidine is the presence of the same =NH group which to a great extent neutralises the acidic character of the isonitroso group. In other words, the acidic character of the isonitroso group is diminished to a certain extent by the presence of the basic =NH group in vicinity, *i.e.*, a kind of intra-molecular neutralisation takes place, and the compound is consequently weakly acidic. Reconciling this fact with the fact that the acid is just as intensely coloured as the salts, the only plausible configuration that can be assigned to isonitroso-malonyl-guanidine is (VII).

This configuration (VII) of isonitroso-malonyl-guanidine, under the influence of strong bases like caustic soda, methylamine, etc., exerts a greater neutralising capacity by tautomerising into a more acidic structure (X) given below :



(X)

And since this configuration is in no way more strained than that of the acid itself (VII), no deepening in colour is expected on salt formation, a fact borne out by actual experiments. And since both the structures contain the highly strained group $\text{N}=\text{O}$, both the acid and the salts are highly coloured.

Another interesting fact that has been found in course of the present investigation is the deepening of colour produced by the substitution of the oxygen atom in violuric acid marked with an asterisk in (I) and (II), by a nitrogen atom ($=\text{NH}$). Similar phenomenon was observed in the case of thiovioluric acid by Lal and Dutt⁵ and also in the case of diphenylthiovioluric acid by Dharan Dass and Dutt.¹ In the present case it has been found that the substitution of a divalent oxygen atom by a divalent $=\text{NH}$ group is nearly as effective in deepening the colour as the divalent sulphur atom.

Isonitroso-malonyl-guanidine does not form salts with weak bases like aniline, quinoline or acridine, but salts with the following bases have been obtained: caustic potash, caustic soda, ammonia, methylamine, ethylamine, n-propylamine, n-butylamine, dimethylamine, diethylamine, trimethylamine, and piperidine. The general properties of these substances as well as their absorption maxima have been given in tabular forms in the experimental portion of the paper.

EXPERIMENTAL

The method available in literature (cf. Traube⁴) for the preparation of isonitroso-malonyl-guanidine was tried, and was found to give an extremely poor yield of an amorphous clay-coloured substance, which the original author also could not obtain in a pure or crystalline condition. The method was thus found to be impracticable for the present purpose, and so after a number of trials, the following method was devised and found to be satisfactory, the yield being almost quantitative. It consists of two stages :

(a) *Preparation of malonyl-guanidine*.—A pasty, intimate mixture of guanidine carbonate (36 gms.) and diethyl-malonate (48 c.c.) was heated on an oil bath at 150° – 160°C for about two hours, when it completely solidified to a very voluminous, perfectly dry, pale pinkish solid. The product is practically pure malonyl-guanidine,

and can be recrystallised from a small quantity of boiling water in thin colourless prisms, but for the preparation of the isonitroso derivative, it is not necessary.

(b) *Preparation of isonitroso-malonyl-guanidine*:—The above crude malonyl-guanidine (12 gms.) was dissolved in dilute caustic soda (100 c.c. of 5% solution) and sodium nitrite (9 gms.) added to the solution and also dissolved in it. The mixture was cooled under the tap and gradually acidified with dilute hydrochloric acid, when the isonitroso derivative came down in the form of a purplish-pink precipitate. This was filtered off, washed with alcohol and water, and crystallised from a large quantity of boiling water in the form of fine radiating needles (*vide* microphotograph given at the end of the paper).

On account of the insolubility of the substance in all organic solvents, the following procedure was adopted for the preparation of salts: the acid was very finely ground up in a mortar with the addition of a little acetone, and a solution of the base in the same solvent added in slight excess. The mixture was kept in a closed flask with occasional stirring for about two days, after which it was filtered off and the excess of the base washed off with acetone and ether. The product was finally crystallised from boiling water and obtained in the form of long thin needles (*vide* microphotograph of the K-salt).

Salts of isonitroso-malonyl-guanidine with inorganic bases are fairly soluble in cold water, but the organic salts are almost insoluble in this solvent, but dissolve in boiling water to a moderate extent, from which they crystallise out on cooling in beautiful forms. Neither the free acid nor the salts have any melting points, but on heating above 250°C, they undergo gradual decomposition with darkening. For want of a suitable organic solvent, the absorption maxima of these substances have been determined in warm aqueous solutions.

Table I

Salts of Isonitroso-Malonyl-Guanidine.

Salt with	Colour in solid state	Remarks	Colour in solution (aq.)	Absorption maxima Å	Analysis. %N (Theoretical in brackets)
Methylamine	Mauve	Curved radiating needles	Violet	5850	36·8 (37·4)
Ethylamine	Ditto	Prismatic needles	Ditto	5830	35·0 (35·0)
Dimethylamine	Ditto	Curved radiating needles	Ditto	5790	34·6 (35·0)
Diethylamine	Ditto	Ditto	Ditto	5810	30·5 (30·8)
Trimethylamine	Ditto	Ditto	Ditto	5810	32·9 (32·5)
n-Propylamine	Ditto	Spindle-shaped crystals	Ditto	5810	33·10 (32·5)

Table I (contd.).

Salt with	Colour in solid state	Remarks	Colour in solution (aq.)	Absorption maxima Å	Analysis. %N (Theoretical in brackets)
n-Butylamine	Mauve	Prismatic needles	Violet	5800	31.1 (30.8)
Piperidine	Ditto	Ditto	Ditto	5825	30.3 (29.04)
Sodium	Deep mauve	Thin rectangular prisms	Deep scarlet	5830	31.3 (31.4)
Potassium	Pinkish mauve	Long needles	Ditto	5835	25.8 (26.4)
Ammonium	Ditto	Curved radiating needles	Violet	5835	39.2 (40.2)
Free acid	Ditto	Needle clusters	Ditto	5860	35.4 (35.89)

Table II

(Figures indicate wavelengths in Angstrom units)

Comparison of absorption maxima of violuric acid, thiovioluric acid and isonitroso-malonyl-guanidine and their organic and inorganic salts

Name of Compound	Of violuric acid	Of thiovioluric acid	Of isonitroso-malonyl-guanidine
Free acid	5305	4403	5860
Ammonium salt	5832	5837	5835
Sodium salt	5832	5828	5830
Potassium salt	5832	5847	5835
Methylamine salt	5782	5829	5850
Dimethylamine salt	5793	5858	5790
Trimethylamine salt	5712	5820	5810
Ethylamine salt	5697	5870	5830
Diethylamine salt	5699	5931	5810
n-Propylamine salt	5832	..	5810
n-Butylamine salt	5532	5850	5800
Piperidine salt	5697	6023	5825

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PLATE I

I. N. DHARAM DASS AND S. DUTT--Isonitroso-malonyl-guanidine



Fig. 1
Crystals of isonitroso-malonyl-guanidine



Fig. 2
Crystals of Potassium salt of isonitroso-malonyl-guanidine

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NEW MONOSTOMES OF THE FAMILY PRONOCEPHALIDAE, LOOSS, 1902

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SUMMARY

The monostomes of the family Pronocephalidae are recorded for the first time from the marine turtles *Chelone mydas* of the Indian sea-coast. *Pronocephalus obliquus* Looss, 1899 the only known species of the genus appears to be the commonest Pronocephalid met with in marine turtles. Variations in the size and position of the genital organs of this species are recorded. Four new species of the genus *Pleurogonius*, i.e., *P. karachii*, *P. sindhii*, *P. chelonii*, and *P. keamarii* have been described. The synonymy of the genera *Pleurogonius* Looss, *Glyphicephalus* Looss, *Barisomum* Linton and *Myosaccus* Gilbert has been discussed and only the first named genus is retained to include the species of these genera. A new species of the genus *Characiephalus* Looss is described and its relationship with the genotype is discussed. A new genus *Renigonius* from the fresh water tortoise *Kachuga dhongoka* is described and its relationships discussed.

INTRODUCTION AND PREVIOUS WORK ON THE FAMILY PRONOCEPHALIDAE

So far the marine turtles near the Indian sea-coasts have never been examined for the investigation of trematodes or even as a matter of fact for any parasitic infections. The present paper comprises the results of investigations on the Digenetic trematodes of the family Pronocephalidae collected from *Chelone mydas* caught at about half a mile distance from the Keamari coast near Karachi during June 1936.

We owe considerably to Looss the knowledge of the family Pronocephalidae Looss, 1902 with a fairly large number of genera and species. This author in his

well-known memoir published in 1902 while giving an exhaustive account of these monostomes laid down a scheme of classification. Before Looss stray contributions had been made by Rudolphi (1809), Von Beneden (1859), Monticelli (1892), Walter (1893), Shipley (1900), and Braun (1901) on *Monostomum trigonocephalum*. But these descriptions as shown by Looss covered two species, one belonging to the genus *Pronocephalus*, i.e., *Pronocephalus obliquus* Looss, 1901 and another to the genus *Pleurogonius*, i.e., *Pleurogonius trigonocephalus* (Rudolphi, 1809) Looss, 1901. Kuhl and Hassett (1822) had described *Monostomum album* which Looss in 1899 included in the genus *Cricocephalus*. Braun in 1901 gave a description of *Monostomum hippocrepsis* Diesing 1855, a parasite of *Hydrochoerus capybara*. The genera created by Looss under this family are: *Pronocephalus* Looss, 1899; *Charaxicephalus* Looss, 1901; *Pleurogonius* Looss, 1901; *Cricocephalus* Looss, 1899; *Glyphicephalus* Looss, 1901; *Epibathra* Looss, 1902; and *Pyelosomum* Looss, 1899.

Linton (1910) described *Cricocephalus delitescens* Looss from loggerhead turtle *Caretta caretta* of the dry Tortugas, and created two new genera *Barisomum* and *Himasomum* with the species *Barisomum crubescens* Linton and *Himasomum candidulum* Linton for the Pronocephalid monostomes of the fishes collected by him in the same locality. Stephens (1911) described the new genus *Desmogonius*. Johnston (1913) published an account of the specimens of *Monostomum pandum* Braun collected by him from *Chelone imbricata* and *Chelone mydas* caught off the Queensland coast (Australia) under his new genus *Diaschistorchis* created for it. Pratt (1914) described a new genus *Wilderia* with the species *Wilderia elliptica* from the loggerhead turtle (*Caretta caretta*) of the Gulf of Mexico. MacCallum (1916) described one new species under the name of *Monostomum Pomacanthi* from the French angel fish and in 1917 a peculiar species *Paramphistomum aspidonectes* from the oviduct of *Trionyx aspidonectes*. He also in 1921 gave an account of *Monostomum sphargidis* MacCallum. Kobayashi (1921) described a new monostome *Cricocephalus koidzumii* from *Chelone mydas* captured at Singapur. Barker in 1922 described a new Pronocephalid *Synechorchis megas* which he considered to resemble much *Monostomum pandum* Braun and *Wilderia elliptica* Pratt, 1914. Travassos (1922) proposed the genus *Hippocrepsis* for *Monostoma hippocrepsis* Diesing 1855 and placed it in the family Notocotyliidae, but Poche in 1925 assigned this genus to the family Pronocephalidae. The latter author in the same paper (1925) created a new genus *Astrorchis* for *Monostomum renicapite* Leidy on account of its star-shaped testes. Poche in describing his supersuper-family Paramphistomida mentions that *Paramphistomum aspidonectes* MacCallum does not belong to the genus *Paramphistomum*. Fukui (1929) proposed for the latter species the genus *Opisthoporus* and the family Opisthoporidae. Price (1931) correctly assigned *Monostomum pomacanthi* (MacCallum, 1916) to the genus *Pleurogonius*. He also redescribed *Paramphistomum aspidonectes* and accepted the genus *Opist-*

hoporus Fukui for it, but he dropped the family Opisthoporidae, transferring the genus to the family Pronocephalidae. He also gave in this paper for the first time after Looss a review of the family giving classification and keys for the identification of the subfamilies and their genera. He recognised three subfamilies Pronocephalinae Looss 1899, Charaxicephalinae Price 1931 and Opisthoporinae Price 1931 and pointed out the synonymy of the genera *Diaschistorchis* Johnston, *Synechorchis* Barker and *Wilderia* Pratt.

Mehra (1932 a and b) described a new species *Diaschistorchis gastricus* and gave the account of a new genus *Neopronocephalus* with two new species, i. e., *N. triangularis* and *N. gangeticus*. He also gave a revision of the family creating two new subfamilies Neopronocephalinae and Hippocrepinae. He transferred the genus *Diaschistorchis* from the subfamily Pronocephalinae Looss to the subfamily Charaxicephalinae Price and amended the diagnosis of the latter subfamilies. He also discussed the synonymy of the genera *Diaschistorchis* Johnston 1913, *Wilderia* Pratt 1914 and *Synechorchis* Barker 1922, accepting the genus *Diaschistorchis* on the basis of priority.

Luhman (1935) recorded the presence of *Pleurogonius trigonocephalus* Rudolphi 1809 and described a new species *Pyclosomum longicacuum* from the loggerhead turtle (*Caretta caretta*). Fukui and Ogata (1936) described a new species of *Diaschistorchis*, *Diaschistorchis takahashii* from *Ocadia sinensis*. Oguro (1936) described a new genus *Medioporus* with two new species, i. e., *M. macrophallus* and *M. cheloniae* from turtles of the Japanese sea, *Eretmochelys squamosa* and *Chelonia japonica* respectively. In the same paper he also described in addition to the three new species *Pyclosomum posteriorchis*, *Pleurogonius oxakii* and *Diaschistorchis lateralis* the already known species, *Cricocephalus albus* Looss, 1899, *Pronocephalus obliquus* Looss, 1899, *Pleurogonius linearis* Looss, 1901, *Glyphicephalus lobatus* Looss, 1901 and *Diaschistorchis pandus* (Braun, 1901) Johnston, 1913. Gilbert (1938) has described three new genera, i. e., *Iguanacola*, *Myosaccus* and *Cetiosaccus* from the marine iguana collected during the Allan Hancock Expedition to the Galapagos Island.

Pronocephalus obliquus Looss, 1899.

More than hundred specimens of this species were obtained from the small intestines of two marine turtles *Chelone mydas* dissected at Karachi. Mostly the worms are mature and show many variations in their size and position of the genital organs, on account of which they differ somewhat from the specimens described by Looss and Oguro. The body measures 3.5 to 6.5 mm. in length and 1.025—1.53 mm. in maximum breadth which occurs in front of the ovary. Immediately behind the characteristic collar there is present on the ventral surface a distinct depression. The oral sucker is rounded with 0.16—2 mm. diameter. The oesophagus is long and

bifurcates into the intestinal caeca at the hinder limit of the collar. The intestinal caeca run parallel to the body length up to the anterior end of the anterior testis

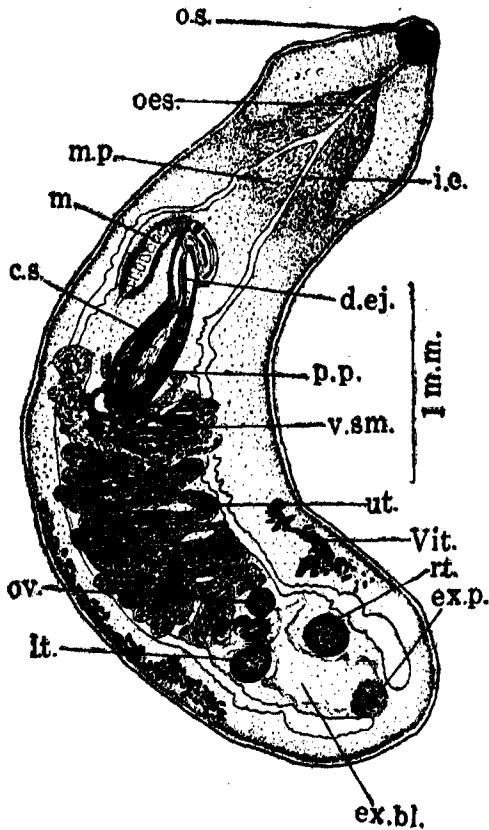


Fig. 1.

Dorsal view of *Pronocephalus obliquus* Looss.

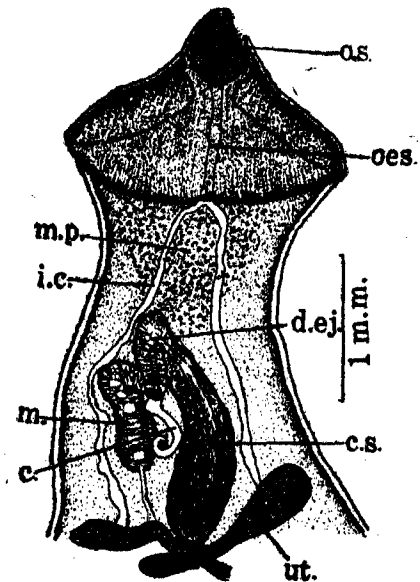


Fig. 2.

Dorsal view of anterior half of *Pronocephalus obliquus* showing the protrusible cirrus.

a.c., anterior cornua of excretory bladder; c., cirrus; c.i.c., cut portions of intestinal caecum; co., collar; c.s., cirrus sac; d.ej., ductus ejaculatorius; d.r., dorsal ridge of the collar; ex.bl., excretory bladder; ex.p., excretory pore; g.o., genital opening; i.c., intestinal caecum; lt., left testis; l.v.d., longitudinal vitelline duct; m., metraterm; m.b.w., muscular body wall; m.p., muscular pimples; oes., oesophagus; o.s., oral sucker; ov., ovary; ovd., oviduct; p., parenchyma; p.c., posterior cornua of excretory bladder; p.g.c., prostate gland cells; ph., pharynx; p.p., pars prostatica; r.t., right testis; s.g., shell gland; t.v.d., transverse vitelline duct; ut., uterus; v.d., ventral depression; vit., vitellaria; v.r., ventral ridge of the collar; v.sm., vesicula seminalis; v.s.m.e., vesicula seminalis externa; v.s.m.i., vesicula seminalis interna; d.

where they slightly bend inwards, terminating in level with the "Rippen" or a little behind it.

The excretory system is in accordance with the description given by Looss. The testes, 0.16–0.414 mm. in diameter, are entire and rounded but in few cases lobed or irregular, equal or unequal, oblique or nearly parallel. The vesicula seminalis lies in transversely arranged coils behind the cirrus sac. The cirrus sac is muscular, measuring 0.72–1.44 mm. in length and 0.18–0.324 mm. in maximum breadth which occurs in posterior half of its length. Its long axis lies parallel to the body length and its anterior end is bent twice forming a U-shaped loop before it opens closely inside the left intestinal caecum. It encloses the pars prostatica surrounded by numerous prostate gland cells, long ductus ejaculatorius and the protrusible cirrus of 0.072 mm. maximum breadth. The latter when protruded has a spirally coiled form as shown in the Fig. 2. The ovary lies a little in front of the testes. It is rounded or oval, entire or lobed, measuring 0.135–0.234 mm. in diameter. The shell gland mass of a rounded or irregular outline lies in level with or a little behind the ovary between it and the left, *i.e.*, the anterior testis. The uterus lies in transverse coils filling the entire intercaecal space between the ovary and cirrus sac, sometimes extending outside the intestinal caeca. The muscular metraterm of 0.45–0.72 mm. length and 0.126 mm. maximum breadth lies almost parallel to nearly one-third terminal part of the cirrus sac. The male and female genital openings lie close to one another in the shallow genital atrium. The ova are provided with a polar filament at each end measuring 0.017–0.02 mm. in length and 0.01 mm. in maximum breadth exclusive of the filaments. The length of the ova is little less than that given by Looss and Oguro in their specimens.

The vitellaria lie laterally in the posterior half of the body outside the intestinal caeca near the body wall. Usually they are of equal length occupying the same distance in front of the ovary as behind it, terminating at the posterior end of the hinder testis. In a few specimens, however, they are of unequal length, the left gland being much larger than the right and extending forward much in front of the latter (Fig. 1). In one specimen the vitelline glands of both the sides are very short and terminate in front of the anterior testis. The transverse vitelline ducts originate at about one-third length of the glands from their hinder end and unite dorsally in the shell gland mass to form the yolk reservoir.

Genus Charaxicephalus Looss, 1901.

Looss in 1901 briefly described a species under the name of *Charaxicephalus robustus* obtained from the stomach of *Chelone mydas*. He, however, in 1902 gave a detailed description of this species and designated it as the type of the genus *Charaxicephalus*. This was the first record of a peculiar member of the family Pronocephalidae Looss, 1902 having a large number of testes arranged in two rows.

Later on two more genera with large number of testes, namely, *Desmogonius* Stephens 1911 and *Diaschistorchis* Johnston 1913 (Syns. *Wilderia* Pratt 1914, *Synechorchis* Barker 1922) were added to the family but so far no other species of the genus *Charaxicephalus* except the genotype has been discovered. In the following pages, I describe the second species of this little known genus.

Charaxicephalus loossi n.sp.

Seven specimens of this species were obtained in 1936 from the first part of the small intestine of one marine turtle *Chelone mydas* obtained from the sea near Karachi (Sind). Out of these seven specimens four I have got in toto preparations and the rest three in vertical and horizontal longitudinal sections. They are thick stout worms of fleshy colour resembling very closely *Charaxicephalus robustus* Looss 1901 in colour, size and shape of the body. The cuticle of these monostomes is very thick, muscular and devoid of spines. The length in pressed specimens measures 7.75 mm. and the breadth measures 1.89–2.02 mm. in the region of the collar, 1.51–1.64 mm. in the region of the cirrus sac and 1.48–1.62 mm. in the region of the ovary. The contracted specimen in entire mount measures 4.32 mm. in length and 1.17 mm. in breadth which is more or less uniform throughout the entire length. The unflattened or contracted specimens possess a groove on the ventral surface which gives the worm a boat-shaped appearance on fixation. The anterior end is narrow and bluntly pointed while the posterior end is broad, flat and produced into two small stumpy protuberances one on each side, which did not appear at all to be mobile in the living worm. The anterior end has got a well developed collar which is characteristic of the genus. As the form and shape of the collar cannot be studied from toto preparations, I have studied it from a series of vertical sections (Fig. 4). The collar is a thickened elevation surrounding the body on all sides unlike that of *Charaxicephalus robustus* which is provided with the lateral lappets and is not continued on the ventral side. Between the ventral part of the collar and the oral sucker there lies a very small rectangular depression or cavity, but this is much smaller than that of *Charaxicephalus robustus* Looss. The ventral surface of the body just behind the collar is deeper and possibly seems for adhesion as mentioned by Looss in the following words "Diese vertiefung fungirt ganz augenscheinlich als ein Haft-organ und ist bei den sammtlichen noch zu beschreibenden Formen mehr oder minder stark ausgebildet und gegen die Bauchfläche abgesetzt."

The sucker lies at the bluntly pointed anterior end and measures 0.5 mm. and 0.45 mm. in transverse and longitudinal diameters respectively in pressed specimens. The oesophagus is narrow tubular structure of 0.68–0.77 mm. length and 0.11 mm. maximum breadth. It bifurcates into the intestinal caeca behind the collar region, at about 1.13–1.23 mm. distance from the anterior end.

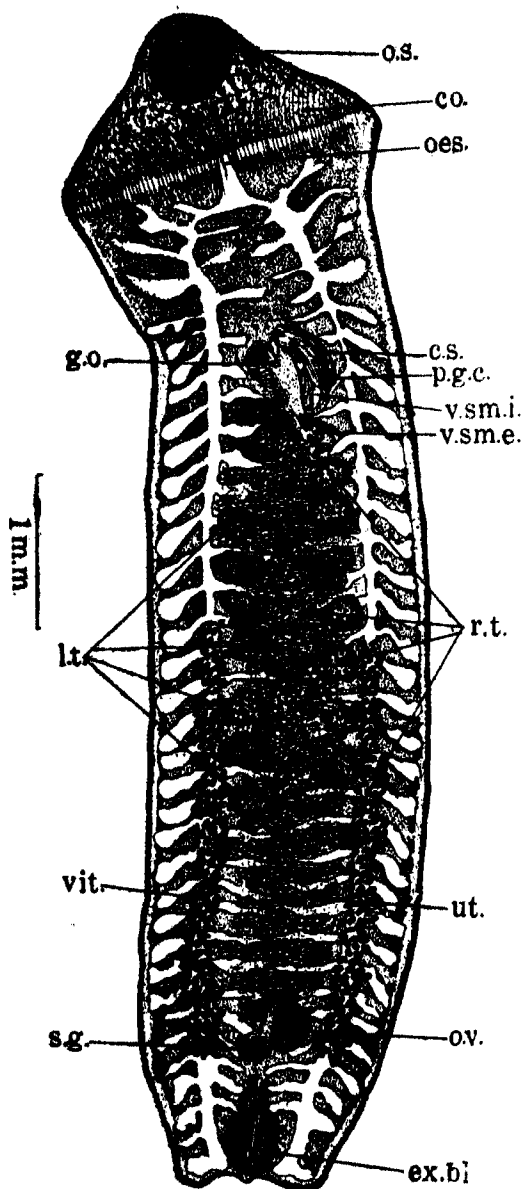


Fig. 3

Dorsal view of *Charaxicephalus loossi* n. sp.

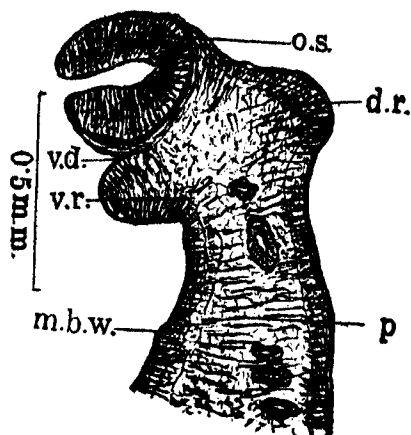


Fig. 4

Vertical longitudinal section of anterior portion of *Charaxicephalus loossi* showing the dorsal ridge of the collar and its ventral portion with a small depression in it.

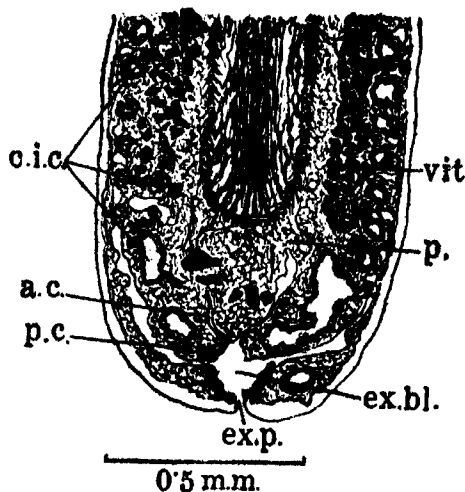


Fig. 5

Horizontal longitudinal section of posterior portion of *Charaxicephalus loossi* showing two pairs of cornua of the excretory bladder originating from the small main stem.

Lettering as in Figs. 1 and 2.

The intestinal caeca as soon as they arise run transversely for a short distance and then bend backwards, occupying a lateral position throughout the entire length of the monostome, extending up to the broad terminal processes and terminating at the extreme hinder end. The intestinal caeca are provided throughout their length with fairly long lateral diverticula notched at the ends. The diverticula directed inwards are nearly transversely placed in the body while those directed outwards are regularly inclined a little backwards, reaching and touching the body wall. The outer and mesial diverticula of both the caeca are nearly equal in number and show a symmetrical arrangement on the two sides of the body.

The excretory pore lies median and terminally at the posterior extremity. The main stem of the excretory bladder, though very small in length, shows the characteristic "Rippen" of Looss, above which it gives off a pair of large cornua one from each side and further forwards a little behind the ovary another pair of smaller and narrower cornua which run inside the intestinal caeca near the median line and end in the region of the shell gland complex and the ovary. The large pair of cornua mainly runs outside the intestinal caeca, parallel to the body-wall extending up to the oral sucker, and giving off branches on both sides mostly inwards throughout their course. The inner branches extend inside the intestinal caeca, and it is not certain on account of the closely situated coils of the uterus filled with numerous ova whether these transverse branches coming from opposite cornua anastomose with one another. The excretory bladder consisting both of the short stem and cornua is lined with a single layer of cells.

The genital opening lies almost median, slightly to the left side at 0.306 mm. distance from the left caecum and 2—2.07 mm. distance, i.e., about one-fourth body length from the anterior end. The testes split up into a number of separate follicles arranged in two lateral rows inside the intestinal caeca. The follicles are constant in number on each side there being always seven on the left and eight on the right side. They are of varying sizes and shapes, usually lobed and irregular but a few follicles have entire margins, measuring 0.18—0.306 mm. in length and 0.162—0.324 mm. in breadth. The size of the various follicles on the two sides is given in the following table :

Table I
Table giving the size of the testes follicles in mm.

Specimen I.	Follicle Number	Size of left testis follicles	Size of right testis follicles
	1	0.198 × 0.288	0.198 × 0.162
	2	0.27 × 0.234	0.27 × 0.234
	3	0.252 × 0.288	0.234 × 0.252
	4	0.216 × 0.27	0.252 × 0.27
	5	0.252 × 0.252	0.234 × 0.288
	6	0.252 × 0.252	0.18 × 0.306
	7	0.234 × 0.288	0.216 × 0.288
	8	...	0.216 × 0.324

Specimen II	Follicle Number	Size of left testis follicles	Size of right testis follicles
	1	0'234×0'27	0'234×0'216
	2	0'252×0'288	0'216×0'27
	3	0'234×0'288	0'216×0'27
	4	0'306×0'252	0'306×0'252
	5	0'27 ×0'288	0'252×0'27
	6	0'288×0'234	0'288×0'27
	7	0'216×0'288	0'252×0'306
	8	...	0'234×0'288

Those on the right side being larger in number commence more anteriorly than those of the left side (right 2'63—2'81 mm. and left 2'8—3 mm. from anterior end). They, however, terminate nearly at the same level, *i.e.*, at about 2—2'34 mm. in front of the posterior end of the body. The thin-walled vesicula seminalis lies as a small knot of coiled tube freely in the parenchyma, confined to the small region between the cirrus sac and the anterior most testis follicle of the right side. The vesicula seminalis interna of 0'1—0'12 mm. length and 0'04 mm. maximum breadth has relatively thick muscular walls and occupies the basal part of the cirrus sac.

The cirrus sac is fairly large measuring 0'63—0'72 mm. in length and 0'216 mm. in maximum breadth. It lies nearly parallel to the long axis of the body inside the right intestinal caecum 1'76—1'89 mm. behind the anterior end and 0'216—0'324 mm. in front of the right testis. Its thick muscular walls are composed of oblique and longitudinal muscle fibres. The vesicula seminalis interna passes by a narrow constriction into the broad pars prostatica of 0'4—0'47 mm. length. The latter has thick muscular walls composed of longitudinal and transversely arranged muscle fibres. Its epithelium has more or less disappeared on account of the inward flow of prostatic secretion through it. The small terminal part of the cirrus sac which is bent and directed backwards contains the ductus ejaculatorius passing into the undifferentiated small protrusible cirrus. The prostate gland cells fill almost the entire space between the vesicula seminalis interna, pars prostatica, ductus ejaculatorius and the walls of the cirrus sac.

The ovary is almost entire and somewhat oval with a more or less straight inner margin measuring 0'32—0'36 mm. in length and 0'25 mm. in maximum breadth. But as examined in serial sections of two specimens it appears to be irregular in shape possibly due to contraction of the body. It lies to the right side of the median line close inside the left intestinal caecum, far behind the hindmost follicle of the right testis, *i.e.*, at 0'77—1'03 mm. distance from it, and 0'65—0'83 mm. in front of the hinder end of the body. The small shell gland mass of nearly rounded form occupies a median position closely inside the posterior end of the ovary and a little behind it. The receptaculum seminis is absent. A small Laurer's canal is

present. The uterus arises from the anterior end of the shell gland mass and passes forwards in numerous strictly inter-caecal and more or less transversely arranged convolutions, which occupy most of the space between the ovary and the cirrus sac. In the region of the vesicula seminalis and the cirrus sac the convolutions are restricted only to the left half of the body. At its terminal end the uterus passes into the well developed metraterm which for the greater part of its length has highly muscular walls composed of transverse and longitudinal muscle fibres. Its proximal muscular part measures 0.2—0.22 mm. in length and 0.09—0.108 mm. in maximum breadth, while the small distal relatively thinner part which is bent backwards measures 0.08—0.1 mm. in length and 0.05—0.055 mm. in breadth. A layer of deeply staining parenchymatous cells surrounds the metraterm and not the cirrus sac contrary to that in *Charaxicephalus robustus* Looss. The genital atrium is shallow so that the male and the female openings are seen to lie side by side close to one another. The ova measure 0.025 mm. in length and 0.015 mm. in maximum breadth. The polar filaments are not discernable possibly on account of the ova being closely packed together in the uterus.

The vitellaria lie laterally in the form of bands beneath the intestinal caeca and are composed of a large number of small follicles of rounded or pear-shaped form. They commence from the fourth or between the fourth and the fifth testis follicles and terminate at the posterior margin of the ovary. The transverse vitelline ducts arise at their hinder ends and unite to form in the median line a very small vitelline reservoir which lies ventrally to the shell gland complex.

Discussion :—This species though it resembles closely in outward appearance the so far only known species of the genus, i.e., *Charaxicephalus robustus* Looss 1901, shows certain important differences from it.

The depression or cavity on the ventral side of the collar is very small as compared with that in *C. robustus* and the protuberances on the hinder end of the body are not cone-shaped as in the latter species. The oesophagus in the new species extends behind the collar region and the intestinal caeca soon after their origin run transversely to the long axis of the body unlike that in the type species. The small stem of the excretory bladder gives off two pairs of cornua, of which the larger pair comparable to the single pair of cornua of *C. robustus* runs mostly outside the intestinal caeca unlike that in the latter species. The testes also differ in their shape, lobed and irregular in *C. loossi* n. sp. and entire in *C. robustus*. They are eight in number on the right side and seven on the left, reverse is the case in the latter species. The cirrus sac in the new species is much larger and lies nearly parallel to the long axis of the body in contrast to that of *C. robustus* which is nearly transversely placed. Looss does not mention whether the small muscular vesicula seminalis interna is present in his species. The shape of the ovary also differs. The shell gland complex lies median extending behind

the ovary while in *C. robustus* it lies to the left side of the ovary. The metraterm in the new species is larger and much more muscular and is surrounded by a sheath of parenchymatous cells. The ova are also smaller in size. The vitellaria are restricted to the posterior half differing slightly from those of *C. robustus* which extends more forwards. In the latter species they commence from the third or between the third and fourth testis follicles while in *C. loossi* they commence further behind, *i.e.*, from the fourth or between the fourth and fifth testis follicles.

Genus *Pleurogonius* Looss, 1899

This is the only genus of the family Pronocephalidae in which more than half a dozen species are known. The type species of the genus, *P. longiusculus* Looss 1901 and one more species *P. trigonocephalum* Looss 1901 were recorded along with *Pronocephalus obliquus* Looss 1901 as early as 1809 by Rudolphi under one and the same specific name *Monostomum trigonocephalum* which Looss in 1901 separated under the two different genera *Pleurogonius* and *Pronocephalus*. The last named author also described in that paper three more species of the genus *Pleurogonius* and two species under another genus *Glyphicephalus* obtained from the turtle *Chelone mydas*. Linton (1910) described in the Helminth Fauna of the Dry Tortugas two new species one under the new genus *Barisomum* and another under the new genus *Himasomum*. Price (1931) has already pointed out that both these genera created by Linton are synonymous. In my opinion the genera *Glyphicephalus* Looss 1901, *Barisomum* Linton 1910 and *Himasomum* Linton 1910 are identical with the genus *Pleurogonius* Looss 1901, and should be considered as its synonyms. MacCallum (1916) described *Monostomum pomacanthi* from the intestine of French angel fish, *Pomacanthus paru*. Price (1931) redescribed this species under its correct generic name *Pleurogonius pomacanthi*. Oguro (1936) recorded the presence of *Pleurogonius linearis* Looss 1901 and described one more species of the genus from *Chelonia japonica* near Japan. The new genus *Myosaccus* created by Gilbert in 1938, for the form obtained from *Amblyrhynchus cristata* is in my opinion identical with the genus *Pleurogonius*. In this paper are described four new species of the genus *Pleurogonius* and there is also given a discussion about the identity of the genera *Glyphicephalus*, *Barisomum*, *Myosaccus* and *Pleurogonius*.

Pleurogonius karachii n. sp.

These monostomes, three in number, were obtained from the middle part of the small intestine of one marine turtle *Chelone mydas* obtained near port Keamari, Karachi. All the specimens of which one is cut in two pieces I possess in entire mounts. The body is narrow, elongated and relatively delicate measuring 4.4 mm. in length and 0.72 mm. in maximum breadth which lies in the collar region. The

breadth of the body behind the collar is uniform throughout, measuring 0.62 mm. The head region of 0.558 mm. length is triangular in outline with the anterior end

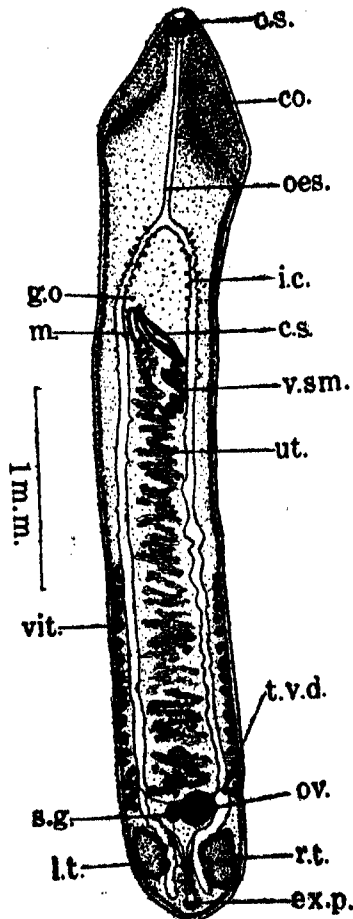


Fig. 6

Dorsal view of *Pleurogonius karachii* n. sp.

Lettering as in Fig. 1.

bluntly pointed and the sucker facing ventrally. The posterior end of the body has a smooth rounded outline. The "Schulterkragen" is represented in this species by two elongated flaps or lappets present on the ventro-lateral sides. The lappets have a characteristic triangular appearance and stand transversely quite apart from one another in the mid-ventral region containing the oesophagus; they are not continuous dorsally to form by their union a transverse ridge. The cuticle is smooth, entirely devoid of spines or pimples. The musculature of the body behind the collar region is very thin.

The oral sucker is rounded, measuring 0.125 mm. in diameter. The pharynx as usual in the family is absent. The oesophagus is narrow and thin-walled extending far behind the collar region and measuring 0.8 mm. in length. The intestinal bifurcation lies in the hinder part of the first quarter of body length, i.e., at 0.93 mm. distance behind the anterior end. The intestinal caeca soon after their origin bend backwards to pursue a straight course parallel to the body length up to the anterior limit of the testes where they bend inwards in the characteristic bow-shaped manner like x passing internally to the latter. In between and behind the testes they lie separated from one another by the median excretory bladder. A few small outgrowths are given off from their sides in the small anterior region behind the intestinal bifurcation, behind which the outgrowths become so scanty that only one or two protuberances here and there may be seen behind the genital opening.

The only part of the excretory system seen is the "Rippen" and the terminal part of the cornua of the excretory bladder. The excretory pore lies dorsally a little in front of the posterior end. It opens into the rosette shaped passage or "Rippen" which leads into the main stem of the bladder. The latter is very small in size and gives off two cornua which run closely parallel to one another in the median line. Behind the ovary the cornua bend outwards but their further course could not be traced.

The genital opening lies close inside the left intestinal caecum, 0.45 mm., behind the intestinal bifurcation. The testes are small with slightly indented margins, measuring 0.252 mm. in length and 0.18 mm. in maximum breadth. They are situated symmetrically opposite one another a little in front of the hinder end of the body outside the intestinal caeca. The small, thin walled, tubular vesicula seminalis lies freely in the parenchyma in the intercaecal space, close to the right intestinal caecum, 1.548 mm., behind the anterior end. It makes a few convolutions and then passes into the cirrus sac which lies obliquely anterior to it, commencing close inside the right intestinal caecum and terminating at the shallow genital atrium situated close to the left caecum. The cirrus sac is very small in proportion to the size of the monostome, measuring 0.324 mm. in length and 0.065 mm. in maximum breadth. It encloses the spindle-shaped pars prostatica which occupies more than three-fourths of its length, the undifferentiated ductus ejaculatorius and cirrus surrounded by the prostate gland cells which occupy all the available space. The cirrus sac, pars prostatica, ductus ejaculatorius and the cirrus are thin-walled without any layer of muscle fibres.

The ovary is large and rounded with entire margins, measuring 0.162 mm. in diameter. It is situated in front of the right testis, close inside the right intestinal caecum at 0.45 mm. distance in front of the posterior end of the body. The small shell gland mass of nearly rounded form and 0.09 mm. diameter lies a

little to the left side of the median line close inside and at the same level with the ovary. The Laurer's canal is not seen. The receptaculum seminis is absent. The uterus arises from the anterior side of the shell gland mass and lies strictly confined to the intercaecal region, in transversely or obliquely arranged coils which are not packed together. Beyond the first few coils in front of the ovary and shell gland mass three or four coils are filled with sperms while the remaining uterus is filled with ova. The small terminal part of the uterus is slightly differentiated as the metraterm which is surrounded by a sheath of parenchymatous cells. The latter opens in the small genital atrium near the male pore.

The ova are small and without polar filaments measuring 0.02 mm. in length and 0.012 mm. in maximum breadth.

The vitellaria lie outside the intestinal caeca between them and the body wall commencing from the posterior two-fifth part of the body length and terminating at about the middle of the ovary. Each vitellarium is composed of a relatively small number of rounded or pear shaped follicles about twenty in number which are arranged in a linear series one behind the other. The transverse vitelline ducts arise from the hinder ends of the vitellaria and pass transversely to the shell gland complex where they unite to form the dorsally situated yolk reservoir.

Discussion :—*Pleurogonius karachi* n. sp. resembles the other species of the genus in the shape of the collar, extent of the intestinal caeca, in the excretory system, and topography of the genital organs. But it differs from all of them in having a long oesophagus, which extends far behind the collar, in the extremely small size of the cirrus sac which lies obliquely in the body, and in the position of the vesicula seminalis to the right of the median line. The shell gland mass also differs in position. In the new species it lies inside the ovary and at the same level with it, whereas in the other species it lies median slightly behind the ovary. Though it does not come near any species of the genus, it combines in itself some characters of *Pleurogonius longiusculus* and others of *Pleurogonius trigonocephalum*. It resembles the former in the equal breadth of the body behind the collar, position of vitellaria within the hinder two-fifth part of the body length and the shape of the testes and the latter species in the size of the body and arrangement of the vitelline follicles which lie behind one another in a linear series.

Host : *Chelone mydas*.

Habitat : Middle part of the small intestine.

Locality : Arabian Sea near Keamari port, Karachi.

Pleurogonius sindhii n. sp.

Six specimens of this species were collected in 1936 from the second half of the small intestine of one and the same turtle *Chelone mydas* from which previously described species was obtained. The worms are small and thick with their cuticle devoid of spines. The pressed specimens measure 2·5–3·78 mm. in length and

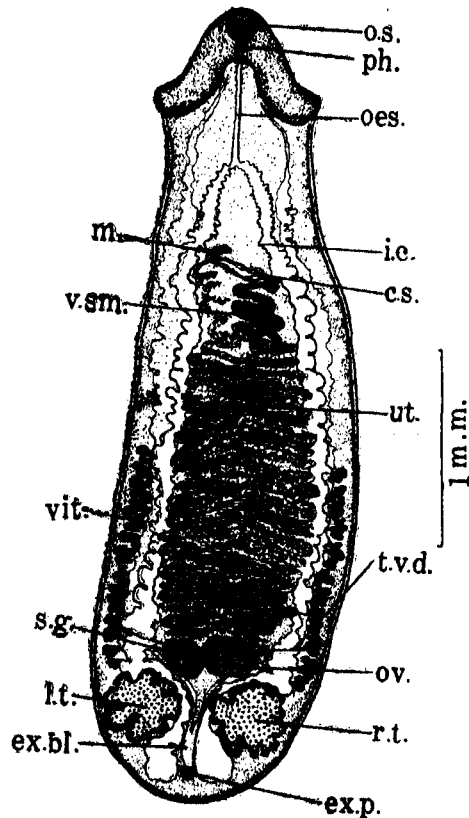


Fig. 7

Dorsal view of *Pleurogonius sindhii* n. sp.

Lettering as in Fig. 1.

0·7–0·81 mm. in breadth in the collar region, 0·81–0·98 mm. in the region of the cirrus sac and 0·72–1·116 mm. in the region of the ovary. The worms show a great power of contraction and extension in living condition and their sides become incurved ventrally giving the worms a boat-shaped appearance. The anterior end is narrow and somewhat bluntly pointed while the posterior end is broad and rounded having the margins incurved ventrally. The collar is characteristic, differing much from that of all the known species of the genus. Its ventrally situated lappets or flaps

are united ventrally behind the oral sucker, and rudimentary pharynx. They also continue into one another on the dorsal surface forming there a small thickened elevation in the form of ridge resembling that in the genera *Pronocephalus* Looss, *Glyphicephalus* Looss and *Barisomum* Linton

The sucker, 0.162 mm. in diameter, is rounded and ventrally situated at the bluntly pointed anterior end. Behind the sucker there is present a very small, rather rudimentary pharynx of 0.045 mm. diameter. This is the first record of the presence of the pharynx, even though rudimentary, in a species of the family Pronocephalidae. The narrow tubular oesophagus measures 0.36–0.58 mm. in length and 0.05 mm. in greatest breadth near the intestinal bifurcation. It lies straight in the median line with its anterior two-third length occupying the collar. The intestinal caeca soon after their origin run backwards in a straight course parallel to the body length up to the anterior limit of the testes where they bend inwards in the same manner as described in the previous species, ending in the neighbourhood of the "Rippen". The caeca are provided throughout their length with regular sac shaped outgrowths. These are much smaller and appear as indentations in the region between the intestinal bifurcation and the cirrus sac, but behind the latter they gradually increase in size.

The excretory pore lies 0.09 mm. in front of the hinder end on the dorsal surface. The passage from it into the bladder shows the "Rippen" of a rounded shape as seen in all the mounted specimens in my possession. The unpaired median stem of the excretory bladder is not so small as known in the other species of the genus *Pleurogonius*. It runs for some distance after its origin from the "Rippen" before it divides into the two cornua at about the middle of the length of the testes. The narrow cornua at first run inside the intestinal caeca parallel to their) (- shaped terminal portion and then pass outwards ventrally in between the caeca and the vitellaria parallel to the longitudinal axis of the body and terminating just behind the union of the collar lappets. The cornua do not unite anteriorly with each other unlike all the other species of the genus. They are provided with outgrowths towards their inner as well as outer sides.

The genital opening lies far behind the anterior end at about one-third body length from it and at 0.36–0.45 mm. distance behind the intestinal bifurcation inside and close to the left caecum. The testes, somewhat large and massive with deeply indented margins, lie as usual in the genus symmetrically opposite to one another in the hinder region of the body outside the intestinal caeca. Both of them are nearly equal in size measuring 0.23–0.26 mm in longitudinal and 0.25–0.4 mm. in transverse diameters. The vesicula seminalis lies freely in the parenchyma behind the cirrus sac slightly to the right side of the median line. It is a thin-walled coiled tube composed of only four or five convolutions, and filled with sperms, measuring 0.062 mm. in greatest breadth. The cirrus sac,

0.18–0.45 mm. in length and 0.0625 mm. in maximum breadth across about its middle, is extremely small relatively to the size of the body as in *Pleurogonius karachii* n. sp. It has thin muscular walls and lies transversely, with a small distal portion of 0.085 mm. length bent anteriorly. The pars prostatica is thin-walled and tubular occupying nearly the entire proximal part of the cirrus sac and measuring 0.0225 mm. in maximum breadth. The ductus ejaculatorius is a fine tube which is sharply separated from the pars prostatica and situated in the distal bent portion of the cirrus sac. The protrusible cirrus is not seen.

The ovary is slightly lobed, measuring 0.108–0.27 mm. in length and 0.216 mm. in maximum breadth. It lies as usual in front of the right testis inside and just in front of the bent terminal part of the right intestinal caecum, 0.36–0.612 mm. away from the hinder end. The large shell gland mass, also irregular in shape, lies to the left side of the median line, closely in contact with the inner margin of the ovary and at the same level with it in front of the left testis. The receptaculum seminis is absent. A small Laurer's canal is present. The uterus arises from the anterior end of the shell gland mass and passes forwards in transversely and obliquely placed coils which are crowded together to form a compact mass filling the entire intercaecal space between the ovary and the vesicula seminalis. In the region of the latter only a few uterine coils confined to the left side of the body are present. A very small dilated terminal part of the uterus of 0.145 mm. length having slightly thickened muscular walls forms the metraterm. The sheath of parenchymatous cells around the metraterm is not seen. The genital atrium is very shallow. The male and female openings are clearly seen lying close to one another in the surface view. The ova are numerous and densely packed in the uterus. They are devoid of polar filaments and measure 0.0225 mm. in length and 0.0125 mm. in maximum breadth.

The vitellaria lie laterally in the posterior half of the body in the form of bands between the intestinal caeca and the body wall, commencing nearly in the middle of the body-length and terminating just in front of the testes. Some vitelline follicles are bilobed. The transverse vitelline duct of each side leaves the gland at the anterior level of the ovary, and runs inwards transversely to open into the vitelline reservoir which lies dorsally on the shell gland complex.

Discussion.—*Pleurogonius sindhii* n. sp. resembles the other species of the genus in the shape of the body, length of the intestinal caeca, position of the excretory pore and topography of the genital organs. But it differs from them in having a transverse dorsal ridge of the collar, a rudimentary pharynx recorded for the first time in the family and transversely placed cirrus sac. Though it stands quite apart on account of these distinctive features it shows resemblance in some characters to *Pleurogonius trigonocephalus* Looss and *Pleurogonius karachii* n. sp. It resembles the former species in size of the body, size and shape of the testes

and ovary, and in the presence of outgrowths of the intestinal caeca throughout their length. It resembles the latter species in size of the cirrus sac, position of the vesicula seminalis, shell gland complex, vitellaria and the transverse vitelline ducts and the arrangement of the vitelline follicles. It also resembles *Pleurogonius ozakii* Oguro, 1936 in the short length of the median stem of the excretory bladder, arrangement of the uterine coils and position of the uterus.

Host : *Chelone mydas*.

Habitat : Second half of the small intestine

Locality : Karachi.

Pleurogonius chelonii n. sp.

Six specimens were obtained from the small intestine of *Chelone mydas* dissected in June 1936 at Karachi. All these specimens one of which is comparatively young, I possess in toto preparations. The young specimen has got all the genital organs developed but its uterus contains only a few ova.

The monostomes measure, when slightly flattened, 2.5–3.9 mm. in length and 0.63–0.97 mm. in maximum breadth which occurs in the middle of the body, i.e., a little in front of vitellaria or in the region of the vesicula seminalis. The breadth of the body is not uniform throughout the body length but it measures 0.63–0.85 mm. in the region of the collar, 0.52–0.66 mm. behind the collar where the body is slightly constricted and 0.6–0.864 mm. in the region of the ovary. The anterior end is slightly pointed with ventrally situated oral sucker while the posterior end is broad and rounded. The collar consists of two ventrally placed lateral lappets connected with one another by a dorsal ridge. The collar lappets as in *Pleurogonius karachii* n. sp. have triangular appearance and stand quite apart from one another in the mid-ventral region which contains the sucker and the oesophagus. The cuticle is devoid of spines. The musculature of the body wall is more strongly developed on the ventral surface just behind the collar where muscular pimples are present. This region probably functions as an adhesive organ.

The oral sucker is rounded measuring 0.12 mm. in diameter. The pharynx is absent. The oesophagus is narrow, thin-walled, extending a little behind the collar and measuring 0.47–0.68 mm. in length. The intestinal bifurcation lies in the hinder part of the first quarter of the body length. The intestinal caeca soon after their origin run obliquely, but behind the cirrus sac they pursue a straight course towards the posterior end parallel to the body length as far as the anterior limit of the testes where they slightly bend inwards in the usual) (-shaped manner as described in previous species. They are devoid of outgrowths in their anterior portion behind the intestinal bifurcation, but behind the metraterm they have got large saccular outgrowths on the outer side only. These latter, however, disappear at their hinder end in the region of the testes.

The oval excretory opening which lies dorsally, 0.126 mm. in front of the hinder end leads into the characteristic "Rippen". The median unpaired stem

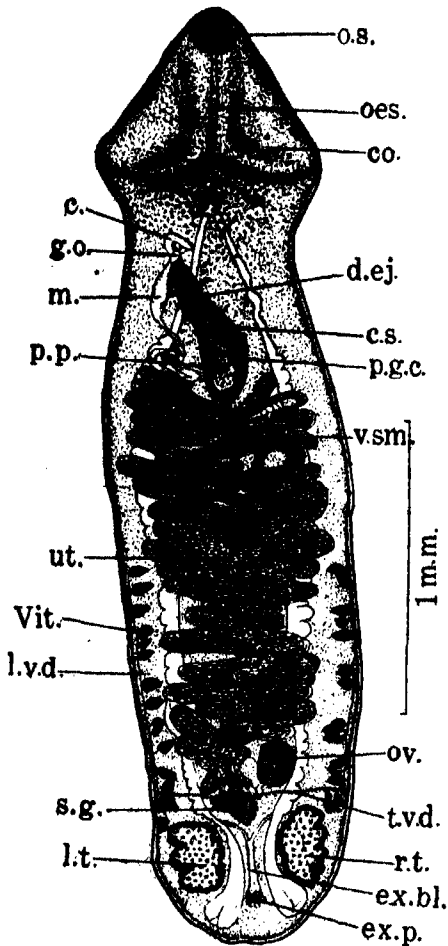


Fig. 8

Dorsal view of *Pleurogonius chelonii* n. sp.

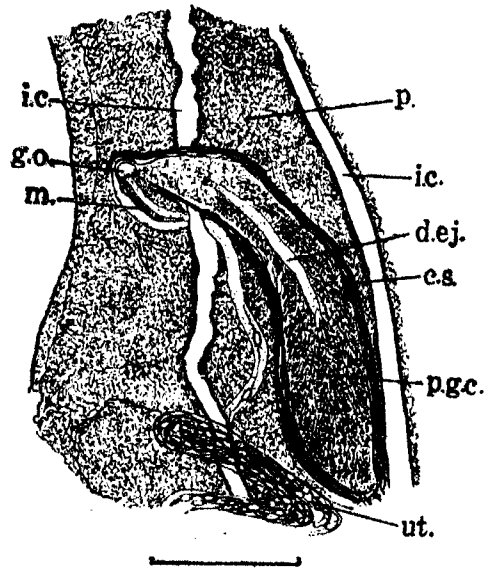


Fig. 9

A portion of *Pleurogonius chelonii* showing the position of genital pore, cirrus sac and metraterm.

Lettering as in Fig. 1 and 2.

of the excretory bladder of nearly 0.144 mm. length bifurcates just behind the shell gland mass. The cornua soon after their origin bend outwards and after crossing the intestinal caeca run ventrally towards the anterior end between the caeca and vitellaria. They terminate in the collar region near the inner angles

of the lappets but without uniting with one another unlike all the other species of the genus described by Looss and Oguro.

The genital opening lies outside the left intestinal caecum a little behind the intestinal bifurcation, 0.81—1.08 mm. away from the anterior end. The testes are situated symmetrically opposite to one another at the hinder end of the body outside the intestinal caeca. They are equal in size, slightly lobed or sometimes rounded and ovoid with entire margins, measuring 0.216—0.36 mm. in length and 0.27 mm. in maximum breadth. In one specimen, however, they are oval and unequal in size, the right testes measuring 0.288 mm. in length and 0.23 mm. in maximum breadth, and the left 0.216 mm. in length and 0.27 mm. in maximum breadth. The vesicula seminalis lies somewhat median freely in the parenchyma outside the cirrus sac. It commences just in front of the anterior limit of the vitellaria and is soon thrown into many transversely arranged coils before it enters by a narrow constriction into the cirrus sac. The cirrus sac is relatively large and muscular measuring 0.55—0.72 mm. in length, *i. e.*, nearly one-fifth of the body length, and 0.15 mm. in maximum breadth which occurs in the posterior half of its length. It lies about two-third body length in front of the hinder end, *i. e.*, 1.75—2.75 mm. distance in front of it. Its posterior half lies median nearly parallel to the body length and then just in front it curves a little towards the left side passing outside the left intestinal caecum to open at the male genital opening. The pars prostatica of 0.18—0.22 mm. length and 0.072 mm. maximum breadth occupies nearly half of the posterior length of the cirrus sac. The long tubular ductus ejaculatorius and small terminal protrusible cirrus have muscular walls. The prostate gland cells fill nearly the entire space in the cirrus sac surrounding the pars prostatica and ductus ejaculatorius.

The ovary is large and rounded with entire margins, measuring 0.144—0.18 mm. in diameter. It lies 0.45—0.67 mm. in front of the hinder end of the body close inside the right intestinal caecum just before the latter bends inwards near its termination in the characteristic bow-shaped manner. The large shell gland mass of irregular shape lies median a little behind the ovary. A small Laurer's canal is present. The receptaculum seminis is absent. The oviduct arises from the inner margin of the ovary and soon enters the shell gland mass to form the ootype. The uterus arises from the anterior margin of the shell gland mass and runs forward in transversely arranged and closely packed coils, which occupy the entire inter-caecal space between the ovary and the cirrus sac, extending outside the intestinal caeca at certain places. The uterus terminates in a small muscular metraterm which lies outside the left caecum and measures 0.125 mm. in length and 0.05 mm. in maximum breadth. The metraterm is surrounded by a layer of deeply staining parenchymatous cells and opens into the genital atrium a little behind the male opening. The ova are small and provided with a long

polar filament at each end, measuring 0.25 mm long and 0.125 mm broad exclusive of filaments.

The vitellaria lie outside the intestinal caeca near the body wall commencing behind the vesicula seminalis and terminating just in front of the testes. Each vitellarium is composed of 14—17 large pear-shaped follicles which are arranged in a linear series one behind the other. The longitudinal vitelline ducts run close to the body wall. They are connected with each follicle by an extremely small connection. The transverse vitelline ducts arise from the hinder ends of the vitellaria and unite dorsally to the shell gland complex to form the vitelline reservoir.

Discussion :—This species resembles *Glyphicephalus lobatus* Looss so closely that at the first appearance it can be mistaken for that species. After a careful study, however, certain important differences are revealed.

The intestinal caeca in *G. lobatus* are provided with outgrowths throughout their length from the intestinal bifurcation, while in the new species the outgrowths of the caeca begin behind the region of metraterm. The chief difference between the two species lies in the position of the genital opening. In the new species the genital opening lies outside the left caecum a little distance away from it, whereas in *G. lobatus* it lies underneath the left caecum. The vesicula seminalis is also much convoluted and differs in size. The ovary is lobed in *G. lobatus* but entire and rounded in *P. chelonii* n. sp. The shell gland mass lies in level with the posterior half of the ovary in the former, but distinctly behind it in the latter. The position of the metraterm also differs; it lies outside the left caecum in the new species, but underneath it in *G. lobatus*. The transverse vitelline ducts lie a little behind the ovary in the new species, but they overlap the latter in *G. lobatus*. These differences justify the creation of a new species for the specimens described above, though at the same time the resemblances clearly indicate the identity of the two genera *Pleurogonius* Looss and *Glyphicephalus* Looss.

Host : *Chelone mydas*.

Habitat : Small intestine.

Locality : Karachi.

Pleurogonius keamarii n. sp.

The monostomes described under this species, five in number, were obtained from the first half of the small intestine of a marine turtle *Chelone mydas* at Karachi. All the specimens, one of which is mutilated, I possess in entire mounts. The worms are small and devoid of spines. The pressed specimens measure 4.5—4.8 mm. in length and 0.96—1.03 mm. in maximum breadth which occurs in the region of the cirrus sac, i.e., a little in front of the vitellaria. The breadth in the collar region of a triangular shape measures 0.81—1.01 mm., in the region immediately behind it 0.9—0.936 mm. and in the region of the ovary 0.88 mm. The

anterior end is bluntly pointed with ventrally situated oral sucker while the posterior end broad and rounded. The collar consists of two ventrally situated

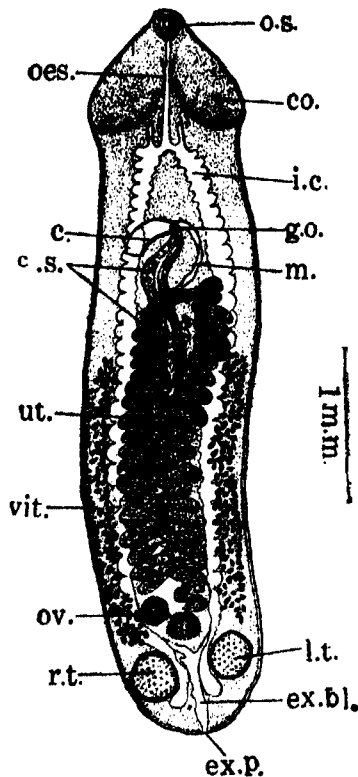


Fig. 10

Ventral view of *Pleurogonius keamarii* n. sp.

Lettering as in Fig. 1.

leaf-shaped lateral lappets connected with one another by a dorsal ridge. The lappets do not meet with one another in the mid-ventral region, i.e., in the region containing the oesophagus. The musculature of the body wall behind the collar is not strongly developed.

The rounded oral sucker is 0.162 mm. in diameter. The pharynx is absent. The narrow thin-walled oesophagus extends a little behind the collar and measures 0.36—0.66 mm. in length. The intestinal bifurcation lies at about one-sixth body length from anterior end. The intestinal caeca soon after their origin bend backwards to pursue a straight course towards the posterior end lying parallel to the body length upto the anterior limit of the testes, where they slightly bend inwards in the usual)(- shaped manner, ending a little in front of the hinder end.

Each caecum soon after its origin gives off a small narrow diverticulum which runs forwards parallel to the oesophagus. Besides these vertical diverticula, the caeca are also provided except in the terminal portions with fairly large saccular outgrowths which are more marked and better developed on the outer side.

The excretory pore lies median at the posterior extremity. The "Rippen" characteristic of the excretory bladder of the genus *Pleurogonius* is absent in this species. The median stem of the excretory bladder bifurcates into the cornua behind the shell gland mass at about 0.54 mm. distance in front of the hinder end. The cornua bend inwards soon after their origin and after crossing the intestinal caeca run forwards ventrally between the latter and the vitellaria, terminating in the collar region just behind the sucker. The stem and the cornua of the excretory bladder are provided throughout their length with many saccular outgrowths.

The genital opening lies almost median slightly to the left side at 1.1–1.45 mm. distance from the anterior end, i.e., at about one-fourth body length from it. The testes are small and rounded with entire margins, measuring 0.252–0.306 mm. in diameter. They are situated symmetrically opposite one another a little in front of the hinder end of the body outside the intestinal caeca. The small thin-walled tubular vesicula seminalis lies freely in the parenchyma just behind the cirrus sac forming a small knot, which is not clearly seen due to the closely packed uterine coils filled with ova. The cirrus sac is relatively large, muscular and nearly of one-fifth body length long, measuring 0.702–1.062 mm. in length and 0.216 mm. in maximum breadth near its base. It lies nearly parallel to the body length in the hinder part of the anterior half and has a characteristic form being constricted in the middle. The constriction divides it into two parts; the posterior part encloses the pars prostatica of 0.288 mm. length and 0.108 mm. maximum breadth surrounded by the numerous deeply staining prostate gland cells, whereas in the anterior part lies enclosed the long, narrow ductus ejaculatorius followed by the large muscular protrusible cirrus. The cuticular covering of the cirrus when seen protruded is distinctly serrated.

The ovary is small and rounded with entire margins, measuring 0.144–0.18 mm. in diameter. It lies as usual in front of the right testis, inside and just in front of the bent terminal part of the right intestinal caecum, at 0.68–0.72 mm. from the hinder end. The small subspherical shell gland mass lies median a little behind the ovary. A small Laurer's canal is present. The receptaculum seminis as usual is absent. The oviduct arises from the inner margin of the ovary and soon enters the shell gland mass to form the ootype. The uterus arises from the anterior end of the shell gland mass and runs forwards in the characteristic double row of transversely arranged coils in the inter-caecal space as far as the constriction of the cirrus sac where the two rows of coils become continuous. The posterior half

of the cirrus sac lies enclosed in between the latter rows of coils. The metraterm is narrow, slightly muscular and crescent-shaped. It lies closely inside the left intestinal caecum. The shallow genital atrium contains the male and female openings situated close to one another. The ova are small and have a long polar filament at each end, measuring 0.03 mm. in length and 0.015 mm. in maximum breadth exclusive of the filaments.

The vitellaria lie laterally one on each side in the posterior half of the body in the form of bands, in between the intestinal caeca and the body wall, commencing nearly in the middle of the body length, *i. e.*, at the base of the cirrus sac, and terminating a little in front of the testes in the region of the shell gland mass. Each gland is composed of a large number of rounded or pear-shaped follicles which lie crowded close to one another. The transverse vitelline ducts arise from the hinder ends of vitellaria and pass inwards to the shell gland complex where they unite to form the dorsally situated yolk reservoir.

Discussion :—*Pleurogonius keamarii* resembles the other species of the genus in the shape of the body, extent and form of the intestinal caeca and topography of the genital organs. It, however, differs from them in the shape of the cirrus sac which is constricted in the middle and consequently divided into two parts. The nearly median position of the genital opening and absence of the "Rippen" are also features in which the new species differs remarkably from the other species. The new species resembles *Glyphicephalus solidus* in having the characteristic narrow vertical outgrowths of the intestinal caeca one on each side of the oesophagus, in the length and form of the vitellaria, shape of the ovary, extent and form of the uterus and size and shape of the ova; but it differs in all the other features some of which as mentioned above are characteristic of this species only.

Host : *Chelone mydas*.

Habitat : First half of the small intestine.

Locality : Karachi.

SYNONYMY OF THE GENERA *PLEUROGONIUS* LOOSS 1901, *GLYPHICEPHALUS*

LOOSS 1901, *BARISOMUM* LINTON 1910 AND *MYOSACCUS* GILBERT 1938.

Looss in 1901 and 1902 published descriptions of the various species of his genera *Pleurogonius* and *Glyphicephalus* along with the other new species and genera of the family Pronocephalidae obtained from the stomach and intestine of marine turtles. Linton in 1910 created also two new genera of this family, *i. e.*, *Barisomum* and *Himasomum* obtained from marine fishes. Price in 1931 pointed out the identity of the genera *Barisomum* Linton, 1910 and *Himasomum* Linton, 1910, which are parasitic in marine fishes. He also showed that the former is closely related to *Glyphicephalus* Looss and *Epibathra* Looss, the only noticeable

difference being in the excretory bladder. In *Barisomum* the cornua of the bladder are united anteriorly, whereas in *Glyphicephalus* they remain separate. In *Epi-bathra*, however, they are connected by transverse anastomosis at their anterior ends. Price feels doubtful whether this difference in the excretory system should be considered as sufficient for the separation of these genera which are identical in every other respect. According to Linton in *Barisomum erubescens* the cornua of the excretory bladder are united by a network of fine vessels in the head region. In the second species of the same genus, i.e., *Barisomum candidulum* Linton syn. *Himasomum candidulum* Linton 1910, only one of these fine branches maintains the connection between the cornua at their anterior end. It, therefore, appears obvious that much weight should not be attached to the union of the cornua of the excretory bladder at the anterior end in separating these genera. The union of the cornua at the anterior end in some of the species of the genus *Pleurogonius* may be due to the joining of one or two opposite branches. In *Pleurogonius karachi* n. sp. and *Pleurogonius sindhi* n. sp. the cornua of the bladder are not united at the anterior end, contrary to the observations of Looss and Oguro on this point in the species of *Pleurogonius* described by them.

After a careful study of the accounts of these genera by their authors and their generic differences according to the keys given by Price (1931) and Mehra (1932), I am able to notice only three points of difference between them which are discussed separately below.

(1) Looss separated the genera *Pleurogonius* from *Glyphicephalus* and *Epi-bathra* on account of the absence of the dorsal ridge like elevation connecting the subventral lobes of the collar in the former and its presence in the latter. Price in his key separated these genera on the basis of this difference, while Mehra in addition to this also laid emphasis on the presence of a sphincter around the terminal part of the stem of the excretory bladder. The figure of vertical section of *Pleurogonius longiusculus* given by Looss, shows clearly the presence of a thick layer of muscle fibres on the dorsal side in the head region indicating the resemblance of a ridge there though its presence is not mentioned in the description of this species. It is possible that Looss on account of the paucity of material at his disposal and also on account of the small size of the specimens he was unable to notice the dorsal ridge, which is present in *Pleurogonius sindhi* n. sp., a species closely related to *Pleurogonius longiusculus* in several characters. In *Barisomum erubescens* Linton also the ridge is not present, while in *Barisomum candidulum* Linton a characteristic muscular collar with dorsal ridge has been described by Linton. So we see that in one species of the genus *Barisomum* the dorsal ridge is present while in the other it is absent. It, therefore, becomes clear that the presence and absence of a dorsal ridge connecting the ventral lappets should not be regarded as a character of sufficient importance for the separation of genera.

(2) The second character which Mehra (1932) has used for the separation of these genera is the presence of the sphincter separating the "Rippon" from the limbs of the excretory bladder in *Pleurogonius* and its absence in *Glyphicephalus* and *Barisomum*. The stem of the excretory bladder in the species of *Pleurogonius* described by Looss is small so that the separation of the cornua from it is marked by a sphincter. But in recently described species of the genus, i.e., *Pleurogonius orakii* Oguro and *Pleurogonius sindhii* n. sp. the stem of the excretory bladder is longer extending nearly up to the posterior region of the shell gland mass and consequently it does not possess a sphincter separating it from the cornua. The presence or absence of a sphincter in the main stem of the excretory bladder should not, therefore, be considered as a character of generic importance when the entire bladder composed of the main stem and cornua is very similar.

(3) The last character used for differentiating these genera is the position of the genital opening. In some species of the genus *Pleurogonius* particularly those described by Looss (1902) and Oguro (1936) the genital opening lies a little inside the left caecum. In the species of the genus *Glyphicephalus* it lies quite close to, inside or underneath the left caecum. In *Pleurogonius pomacanthi* MacCallum; (1916), *Pleurogonius chelonii* n. sp. and in two species of *Barisomum* described by Linton the genital opening lies just outside the left caecum. In *Pleurogonius keamarii* n. sp. it lies much inside the left caecum i.e., a little to the left side of the median line, though in every other respect this species resembles *Glyphicephalus solidus* Looss. It, therefore, follows that the position of the genital opening varies in different species of the genus *Pleurogonius*, from a little to the left side of the median line to that just outside the left caecum. There is hardly any distinction between these genera in regard to the position of the genital opening. The position varies within such limits as would separate the different species of the same genus. The genus *Myosaccus* Gilbert, 1938 in my opinion is untenable. The position of the male and female genital openings, which lie separately close to one another outside the left intestinal caecum, is similar to that of *Pleurogonius chelonii* n. sp. and the two species of *Barisomum*. The other distinctive characters of *Myosaccus* i.e., the presence of separate male and female openings and a large number of polar filaments at each pole of the ovum, should be considered as features of specific importance only.

The above discussion leads us to the conclusion that the genera *Pleurogonius*, *Glyphicephalus*, *Barisomum* and *Myosaccus* are identical and should be considered as synonymous, the first name being accepted on the basis of priority. The genus *Epibathra* Looss as Mehra (1932) has pointed out is not a synonym of the genus *Pleurogonius*. Not only does the excretory system of the two genera differ (many transverse anastomoses connect the cornua in *Epibathra*, but they are absent in *Pleurogonius*, *Glyphicephalus*, *Barisomum* and *Myosaccus*), but the position of the

testes in relation to the caeca also differs markedly. In *Epibathra* the testes overlap the terminal ends of the caeca, but it is not the case in the genera discussed above.

Emended diagnosis of the genus *Pleurogonius*

Body very small to middle-sized, with poorly developed musculature of body wall. Collar with conspicuous ventrally situated lateral lappets, dorsal ridge uniting lappets present or absent; cavity on the ventral surface just behind collar present. Intestinal caeca with or without outgrowths as far as anterior limit of testes, where they bend in a characteristic () (-shaped manner, terminating in the neighbourhood of excretory pore. Excretory bladder usually provided with "Rippen," i.e., rosette-shaped funnel part; main stem of excretory bladder usually short, sometimes a little longer extending as far forwards as shell gland mass where it divides into two cornua, which run between intestinal caeca and body wall extending up to collar region where they may or may not unite with one another. Genital pore behind intestinal bifurcation from a little to left side of median line and inside left caecum to near left body margin outside left caecum. Testes entire irregular or lobed, extracaecal, symmetrically opposite at hinder end of body. Vesicula seminalis coiled and external. Cirrus sac large or small, curved or straight, intercaecal, situated parallel, obliquely or transversely to body length. Ovary entire or lobed situated closely inside right caecum in front of right testis. Laurer's canal present. Receptaculum seminis absent. Shell gland mass compact, median, in level with or slightly behind ovary. Vitellaria extra-caecal in posterior half of body, terminating in front of testes. Transverse vitelline ducts originate at posterior end of vitellaria; yolk reservoir on dorsal side of shell gland mass. Uterine convolutions transversely or obliquely arranged, filling almost entire intercaecal space between ovary and cirrus sac, sometimes extending outside the caeca. Metraterm with or without musculature. Eggs small with or without polar filaments.

Habitat: Intestine of marine fishes and turtles.

Type species: *Pleurogonius longiusculus* Looss, 1901.

Renigonus orientalis nov. gen., nov. sp.

Only one specimen of this rare monostome was found by Dr. H. R. Mehra from the stomach of *Kachuga dhongoka*—a common tortoise in the rivers Ganges and Jumna at Allahabad. The flattened specimen measures 2.28 mm. in length and 0.953 mm. in maximum breadth which lies in the posterior half of the body at the commencement of the vitellaria. The anterior end, 0.09 mm. in width, is bluntly pointed with the sucker facing ventrally; the breadth in the region of

collar measures 0.558 mm, in that of the intestinal bifurcation 0.684 mm., and in that of the ovary and the anterior part of the testes 0.9 mm. The anterior region

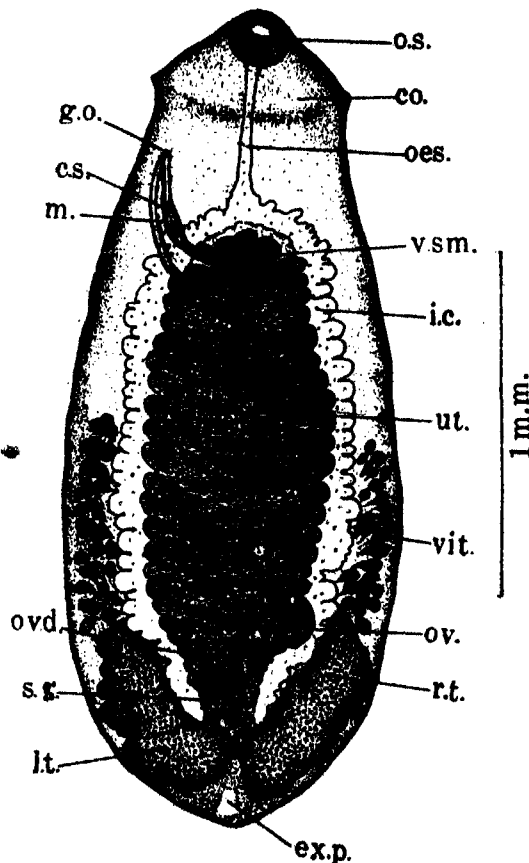


Fig. 11

Dorsal view of *Renigonius orientalis* nov. gen., n. sp.

Lettering as in Fig. 1.

of the worm, triangular in shape and 0.234 mm. in length, is encircled by the characteristic muscular collar. As usual in the family it is distinguished as the thickened and muscular anterior part of the body. It is, however, not so prominently developed in this genus than in other members of the subfamily Prouncephalinae Looss, and moreover it is entirely devoid of lateral lappets. The hinder end of the body is broad and somewhat rounded.

The sucker measures 0.135 mm. in length and 0.153 mm in maximum breadth. The pharynx as usual in the family is absent. The oesophagus of 0.432 mm. length is a long narrow and straight tube which slightly broadens just before it bifurcates

into the intestinal caeca. The intestinal bifurcation, 0.072 mm in breadth, lies at the end of the anterior one-fourth body length, *i.e.*, 0.567 mm. from the anterior end of the body and 0.18 mm. behind the collar. The intestinal caeca do not run transversely as they arise from the intestinal bifurcation as in many Pronocephalids, but they pass somewhat obliquely downwards pursuing a straight course parallel to the sides of the body, till at about three-fourth body length from the anterior end they bend inwards closely inside the testes, terminating a little in front of the posterior end *i.e.*, 0.27 mm in front of it. They are not) (-shaped near their hind ends in the region of the testes as in the genus *Pleurogonius*. They are nearly twice as broad as the oesophagus and are provided throughout their entire length with small lobe-like outgrowths on their outer as well as inner sides. These outgrowths which are much more numerous on the outer than on the inner side are quite broad and saccular and are situated close to one another.

The excretory system is not seen in the entire mount. The excretory pore is situated dorsally near the hinder end behind and between the testes. The "Rippen" characteristic of the excretory bladder of the Pronocephalids is absent here.

The testes are large, elongated antero-posteriorly and are nearly kidney-shaped with their convex outer side produced into lobes. They lie symmetrically opposite one another in the hinder one-fourth part of the body outside the terminal part of the intestinal caeca between them and the body wall with their anterior ends directed outwards and the posterior ends near the median line. They are so situated that they form together the two arms of the letter V, a position which is quite characteristic of this genus. As the intestinal caeca stop short of the posterior end of the testes, the hinder ends of the latter, 0.18 mm. in length, have come to lie near one another converging towards the median line. The testes are about equal in size, measuring 0.54 mm. in length and 0.25 mm. in greatest breadth. The cirrus sac is small, narrow, tubular and slightly curved with thin walls measuring 0.324 mm in length and 0.0475 mm in greatest breadth which lies near its middle. Its proximal portion lies dorsally to the left intestinal caecum at a distance of 0.09 mm from the intestinal bifurcation. The distal two-third of its length lies extra-caecal somewhat parallel to the long axis of the body near the left body margin opposite the hinder part of the oesophagus. The cirrus sac opens to the exterior by its narrow end at the genital opening, which lies close to the left body margin in the region of the oesophagus, 0.126 mm. distance behind the collar. The vesicula seminalis, thin-walled and full of sperms lies as usual in the family outside the cirrus sac closely behind the intestinal bifurcation. It is straight proximally overlapping the uterine coils and commencing a little in front of the anterior ends of the vitellaria, but distally before entering the cirrus sac it becomes much coiled forming a knot shaped mass.

The lobed ovary, 0.162 mm. in length and 0.2 mm. in maximum breadth, lies to the right side closely inside and partly overlapping the right intestinal caecum in level with the anterior end of the testes, and at 0.47 mm. distance in front of the hinder end of the body. The large shell gland mass of nearly rounded form lies median a little behind the ovary in the narrow space between the terminal ends of the intestinal caeca, measuring 0.12 mm. in diameter. The oviduct, 0.125 mm. in diameter, originates from the inner side of the ovary near its posterior end and forms a few narrow coils before it passes into the ootype which is surrounded by the shell gland cells. The receptaculum seminis is absent. The Laurer's canal is not seen. The uterus arises from the shell gland mass on the side opposite to that of the oviduct and first passes backwards forming a few coils, which separate the two testes and then turns forwards to form the huge mass of ascending uterine coils, which are transversely arranged very close to one another packing nearly the entire space between the intestinal caeca. The metraterm is a narrow slightly curved tube running closely outside the cirrus sac. Its proximal portion overlaps dorsally to the left intestinal caecum. The ova measure 0.0225 mm. in length and 0.01 mm. in maximum breadth. The polar filaments are not seen.

The vitellaria lie outside the caeca between them and the body wall commencing a little behind the proximal end of the vesicula seminalis at about the middle of the body length terminating immediately in front of the anterior end of the testes. They are composed of a relatively small number, *i.e.*, about twenty-five pear-shaped or rounded follicles of 0.025–0.063 mm. diameter.

Discussion.—This interesting parasite is assigned to the sub-family Pronocephalinae Looss as defined by Mehra (1932) with which it presents unmistakeable affinities on account of the position of the testes behind the ovary in the hinder part of the body and the position of the genital opening which lies to the left side of the median line. It seems to be closely related to *Pleurogonius* Looss, 1901 on account of the topography of the genital organs but it differs from it in the intestinal caeca terminating in front of the posterior end of the testes, in characteristic shape and position of the latter, absence of the "Rippen" in the terminal part of the excretory bladder, and position of the genital pore, which lies anterior to the intestinal bifurcation. The cirrus sac in the genus *Pleurogonius* lies in the inter-caecal space while in the new genus remarkable for its small size and thinness of its walls it lies on and outside the left intestinal caecum. The collar in *Renigonius* n.g. also markedly differs in shape and in the absence of lappets contrary to that in all the genera of the subfamily Pronocephalinae. The above-mentioned differences and special features characterising this monostome entitle its elevation to the rank of a new genus, which is named *Renigonius* on account of its kidney-shaped testes.

Diagnosis of the genus *Renigonius* nov. gen.

Pronocephalinae of small size. Collar continuous dorsally and ventrally surrounding the head, conical in shape; hinder end broad and rounded. Pharynx absent; oesophagus long; intestinal bifurcation at about anterior one-fourth body length from anterior end; intestinal caeca bend inwards to testes, terminating a little in front of the hinder end of the latter. Testes massive, kidney-shaped, symmetrically situated one on each side outside caeca at posterior end of body in V-shaped manner. Cirrus sac very small and tubular, partly overlapping and partly outside left intestinal caecum. Vesicula seminalis external, coiled and inter-caecal. Pars prostatica and ductus ejaculatorius small and undifferentiated within cirrus sac. Ovary dextral, slightly overlapping right intestinal caecum opposite anterior end of testes. Shell gland complex median a little behind ovary. Uterus pre and post ovarian filling entire inter-caecal space with coils transversely arranged. Metraterm small, tubular and to left side mainly outside to left intestinal caecum. Genital pore to left side near body wall in front of intestinal bifurcation. Vitellaria pretesticular, extracaecal, and composed of a small number of about twenty-five follicles each. Excretory opening dorsal and subterminal; "Rippen" of excretory bladder absent. Ova oval, 0.0225 mm. in length and 0.01 mm. in maximum breadth.

Habitat: Stomach of fresh water turtle *Kachuga dhongoka*.

Locality: Ganges, Allahabad.

Type species: *Renigonius orientalis* nov. gen., nov. sp.

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FORMATION OF PERIODIC PRECIPITATE IN THE ABSENCE OF A FOREIGN GEL, PART III—FERRIC PHOSPHATE AND FERRIC ARSENATE SOLS

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SUMMARY

This paper gives a study of periodic precipitation of ferric phosphate and ferric arsenate sols by the process of coagulation with electrolytes. The speed of coagulation, the nature of coagulum and the adsorption of sol have been investigated to elucidate this phenomenon.

In part II of this series¹ it has been shown that for the formation of periodic precipitates in the absence of a foreign gel, there are three factors which guide the process, *viz.*, (1) the speed of coagulation of sol by electrolytes, (2) the nature of coagulum yielded which settle periodically and (3) the adsorption of sol by its own precipitate. It has also been shown that the adsorption of sol by its own precipitate is fairly general in colloids whether they produce rings or not. In view of these, it has been desirable to investigate how far the three factors are responsible in the formation of rings in ferric phosphate and ferric arsenate sols and the results are recorded below.

FERRIC PHOSPHATE SOL

The sol was prepared by adding dihydrogen sodium phosphate to ferric chloride solution. The sol was subjected to cold dialysis and aliquot parts were taken out for investigations. After 24 hours of cold dialysis the sol contained 0.308 gm. atom of Fe per litre and its purity was 0.505. It was diluted to 0.0616 gm. atom and 0.0308 gm. atom of Fe per litre respectively. 10 c.c. of these sols were mixed with 10 c.c. of electrolytes of different concentrations and kept for 24 hours to note the condition of the coagula. From the total volume of 20 c.c., 9 c.c. of the suspension were taken out after thorough shaking and subjected to centrifuge for 5 minutes. The compact volumes of the coagula obtained after centrifuging were noted.

Table I

Sol containing 0.0616 gm. atom of Fe per litre.

9 c. c. of the suspension contain 0.0002772 gm. atom of Fe.

Amount of N/10 K_2SO_4	Volume of coagulum	Amount of precipitate getting peptised
5.0 c.c.	1.0 c.c.	Nothing
4.0 c.c.	1.0 c.c.	Nothing
3.5 c.c.	Partial coagulation	

With this concentration of the sol, no rings were obtained by coagulating with K_2SO_4 . The coagula were all in gel state and no settling occurred. The sol could not be coagulated with KCl.

Table II

Sol containing 0.0308 gm. atom of Fe per litre

9 c. c. of the suspension contain 0.0001386 gm. atom of Fe.

Amount of N/10 K_2SO_4	Volume of coagulum	Amount of precipitate getting peptised
3.0 c.c.	0.4 c.c.	0.000028 gm. atom
2.5 c.c.	0.5 c.c.	0.000050 gm. atom
2.0 c.c.	0.7 c.c.	0.000086 gm. atom
1.5 c.c.	Partial coagulation	

With this concentration of the sol, quite prominent rings (Plate I) developed with 3.0 c.c. and 2.5 c.c. of K_2SO_4 . With 2 c.c. of the electrolyte no rings developed as the coagulum was in gel state and no settling occurred after 24 hours.

SPEED OF COAGULATION

To find out the speed of coagulation of the sol, 10 c.c. of the sol containing 0.07378 gm. atom of Fe per litre, were mixed with the electrolyte, the total volume being 20 c.c. Such similar mixtures were taken in separate test-tubes and 8 c.c. from each were centrifuged for 5 minutes after definite intervals. The amounts of the solid matter left in sol state were estimated in each case.

Table III

5.5 c.c. of N/10 K_2SO_4 made up to 10 c.c. coagulated 10 c.c. of the sol in 1 hour (precipitating concentration).

Time	Amount left in sol state out of 0.000295 gm. atom of Fe
After 2 minutes	No coagulation
After 15 minutes	0.000264 gm. atom
After 30 minutes	0.000144 gm. atom
After 60 minutes	0.000120 gm. atom

The original sol was further purified by cold dialysis for 2 days. It contained 0.238 gm. atom of Fe per litre and its purity was 1.14. It was diluted to 0.0238 gm. atom of Fe per litre.

Table IV

Sol of concentration of 0.0238 gm. atom of Fe per litre.		
9 c.c. of the suspension contain 0.000107 gm. atom of Fe		
Amount of N/40 K_2SO_4	Volume of coagulum	Amount of precipitate getting peptised
5.0 c.c.	0.4 c.c.	0.000023 gm. atom
4.5 c.c.	0.5 c.c.	0.000027 gm. atom
4.0 c.c.	Partial coagulation	

With this concentration and purity of sol, only broken rings developed with K_2SO_4 . The speed of coagulation with this bivalent electrolyte at its precipitating concentration increased as will be seen from the following table.

SPEED OF COAGULATION

Table V

4.0 c.c. of N/40 K_2SO_4 made up to 10 c.c. coagulated 10 c.c. of the sol almost instantaneously (precipitating concentration).

Time	Amount left in sol state out of 0.000295 gm. atom of Fe
After 2 minutes	0.000130 gm. atom
After 15 minutes	0.000056 gm. atom
After 30 minutes	0.000040 gm. atom
After 60 minutes	0.000040 gm. atom

The original sol was further purified by cold dialysis for 2 days. It contained 0.196 gm. atom of Fe per litre and its purity was 1.92. It was diluted to 0.0196 gm. atom and 0.0098 gm. atom of Fe per litre respectively.

Table VI

Sol containing 0.0196 gm. atom of Fe per litre.		
9 c.c. of the suspension contain 0.000088 gm. atom of Fe.		
Amount of electrolyte	Volume of coagulum	Amount of precipitate getting peptised
4.36N KCl		
3.0 c.c.	1.0 c.c.	Nothing
2.0 c.c.	1.0 c.c.	Nothing
1.0 c.c.	Partial coagulation	
N/40 K_2SO_4		
2.5—4.0 c.c.	0.6 c.c.	Nothing

With this concentration of the sol, no well-defined rings developed with KCl, as the coagula were all in gel state and no settling occurred after 24 hours. K_2SO_4 coagulated the sol almost instantaneously and no rings developed with this electrolyte.

Table VII

Sol containing 0.0098 gm. atom of Fe per litre.		
9 c.c. of the suspension contain 0.000044 gm. atom of Fe.		
Amount of	Volume of	Amount of precipitate
4.36N KCl	coagulum	getting peptised
5.0—4.0 c.c.	0.5 c.c.	Nothing
3.0—1.0 c.c.	0.6 c.c.	Nothing
0.5 c.c.	Partial coagulation	

With this concentration of the sol, quite prominent rings developed with 4 c.c. and 5 c.c. of KCl. Though lower concentrations of it coagulated the sol completely, yet the coagula were in gel state and no settling occurred after 24 hours. No rings developed with K_2SO_4 as coagulant.

SPEED OF COAGULATION

Table VIII

7.0 c.c. of 4.36 N. KCl. made upto 10 c.c. coagulated 10 c.c. of the sol in 1 hour (precipitating concentration).

Time.	Amount left in sol state out of 0.000295 gm. atom of Fe
After 2 minutes	No. coagulation.
After 15 minutes	0.000284 gm. atom.
After 30 minutes	0.000179 gm. atom.
After 45 minutes	0.000105 gm. atom.
After 60 minutes	0.000058 gm. atom.

ADSORPTION OF SOL

Freshly precipitated ferric phosphate was freed from the adsorbing electrolyte and was suspended in distilled water. Definite volumes of the suspension were taken in several 100 c.c. flasks with 5 c.c. of the sol of known strength. Different amounts of electrolyte were added to these flasks and the total volumes were made upto 100 c.c. The flasks were vigorously shaken and allowed to settle for 24 hours. The supernatant clear liquids containing iron in sol condition were gently pippered out and estimated. From the amount of iron introduced the percentage adsorption of the sol by the precipitate was determined in each case.

Table IX

Sol of purity 0.988.

Amount of the precipitate taken each time 0.80 gm. of Fe.

Amount of the sol taken each time 0.067 gm. of Fe.

Amount of N/20 K ₂ SO ₄	Amount of Fe left in sol state	%Adsorption
0 c.c.	0.063 gm.	6.0
1 c.c.	0.063 gm.	6.0
3 c.c.	0.060 gm.	10.45
5 c.c.	0.056 gm.	16.42
7 c.c.	0.027 gm.	59.70
9 c.c.	0.000 gm.	100.00

In absence of the precipitate, the same amount of the sol required 6.2 c.c. of the electrolyte for partial and 9.0 c.c. for complete coagulation.

Table X

Sol of purity 0.988.

Amount of the precipitate taken each time 0.80 gm. of Fe.

Amount of the sol taken each time 0.067 gm. of Fe.

Amount of 2N KCl	Amount of Fe left in sol state	%Adsorption
0 c.c.	0.063 gm.	6.00.
1 c.c.	0.060 gm.	10.45.
3 c.c.	0.044 gm.	34.33.
5 c.c.	0.033 gm.	50.74.
7 c.c.	0.024 gm.	64.18.
9 c.c.	0.013 gm.	80.60.
11 c.c.	0.002 gm.	97.01.
13 c.c.	0.000 gm.	100.00.

In absence of the precipitate, the same amount of the sol required 18.0 c.c. of the electrolyte for partial and 22.4 c.c. for complete coagulation.

FERRIC ARSENATE SOL.

The sol was prepared by adding dihydrogen sodium arsenate to ferric chloride solution with constant shaking. The sol was subjected to cold dialysis for 48 hours. It contained 0.244 gm. atom of Fe per litre and its purity was 0.61. A portion of it was diluted to 0.488 gm. atom of Fe per litre.

Table XI

Sol containing 0.0976 gm. atom of Fe per litre.

9 c.c. of the suspension contain 0.0004392 gm. atom of Fe.

Amount of N/10 K_2SO_4	Volume of coagulum	Amount of precipitate getting peptised
6.5 c.c.	0.5 c.c.	0.000276 gm. atom.
6.0 c.c.	0.5 c.c.	0.00036 gm. atom.
5.5 c.c.	Partial coagulation	

With this concentration of the sol, quite prominent rings developed with K_2SO_4 . The sol could not be coagulated with KCl.

SPEED OF COAGULATION

Table XII

3.0 c.c. of N/10 K_2SO_4 made up to 10 c.c. coagulated 10 c.c. of the sol in 30 minutes (precipitating concentration).

Time	Amount left in sol state out of 0.000295 gm. atom of Fe
After 2 minutes	No coagulation.
After 15 minutes	0.000280 gm. atom.
After 30 minutes	0.000136 gm. atom.
After 60 minutes	0.000136 gm. atom.

ADSORPTION OF SOL

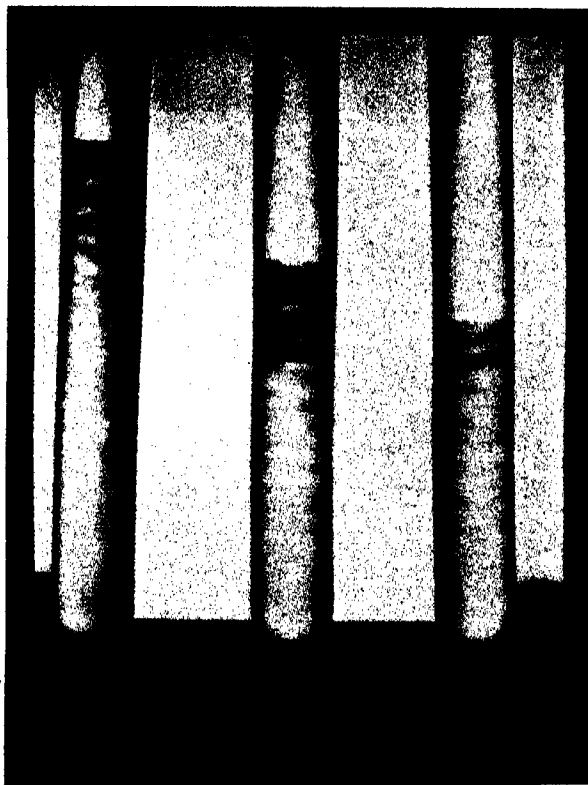
There was sufficient adsorption of the sol by its own precipitate in presence of KCl but in the presence of K_2SO_4 there was hardly any adsorption.

The original sol was further purified by cold dialysis for 3 days. It contained 0.184 gm. atom of Fe per litre and its purity was 1.63. It was diluted to 0.0736 gm. atom of Fe per litre. No rings developed in this sol with K_2SO_4 as coagulant because the speed of coagulation of the sol with the bivalent electrolyte was rapid. On further purification, the sol produced stiff gels on coagulation.

From the above results it may be seen that ferric phosphate and ferric arsenate sols produce rings on coagulation with bivalent coagulating ions from K_2SO_4 . When these sols are very impure, K_2SO_4 produce slow coagulation (cf. Tables III and XII). This is due to the presence of large amounts of the stabilising electrolytes in impure stages. The nature of the coagulation-velocity curves are also S-shaped. First the coagulation proceeds very slowly and then increases quickly and finally falls off again. This auto-catalytic nature of the curves is probably due to the adsorption of sol by its own precipitate. With gradual appearance of

PLATE I

R. N. MITTRA—*Ferric Phosphate and ferric arsenate sols.*



Periodic precipitate of ferric phosphate sol.

the coagulum, the adsorption increases enormously. This is further supported by the peptisation of precipitate when the coagulum which settles periodically is subjected to centrifuge. The sol which is loosely adsorbed by the coagulum gets out when the latter is pressed under the force of centrifuge. With gradual purification of the sols the coagulation with K_2SO_4 is almost instantaneous and no rings develop there. The data on the speed of coagulation also show curves of asymptotic type (*cf.* Table V). Moreover at slow coagulation with K_2SO_4 , the coagulum settles periodically when the optimum volume of coagulum is 0.5 c.c. On further dialysis the sols are coagulated by KCl; the ferric phosphate sol produce rings with this electrolyte at the optimum volume of coagulum of 0.5 c.c. But in case of ferric arsenate sol of moderate purity it behaves like lyophilic one and the coagulum obtained by coagulating with KCl is gel-like in nature which does not settle even on long standing; and if very dilute sol is taken, the amount of coagulum falls short to give rise to periodicities.

From the data on the adsorption of sol, it may be concluded that there is adsorption of sol by its own precipitate at any purity and purer the sol the greater the adsorption. Table VI also shows that in moderately pure sols there is no peptisation of precipitate on centrifuging or the adsorption is more firm in those cases where generally no rings develop.

Thus when the speed of coagulation of sols by either mono-or bi-valent coagulating ions is more or less S-shaped and the optimum of volume of coagulum under the conditions already stated is 0.5 c.c. the sols give rise to periodic precipitates.

Reference

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FORMATION OF PERIODIC PRECIPITATE IN THE ABSENCE OF A FOREIGN GEL, PART IV—FERRIC BORATE SOL

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SUMMARY

This paper gives a study of periodic precipitation of ferric borate sol by the process of coagulation with electrolytes. The speed of coagulation, the nature of coagulum and the adsorption of sol by its own precipitate have been investigated to elucidate the phenomenon.

FERRIC BORATE SOL

The sol was prepared by adding a saturated solution of borax to ferric chloride solution with constant shaking. The resulting sol was subjected to cold dialysis for 6 days. It contained 0.198 gm. atom of Fe per litre and its purity was 1.24. It was diluted to 0.0594 gm. atom, 0.0396 gm. atom and 0.0198 gm. atom of Fe per litre respectively.

Table I

Sol containing 0.0594 gm. atom of Fe per litre.

9 c.c. of the suspension contain 0.0002674 gm. atom of Fe

Amount of N/40 K_2SO_4	Volume of coagulum	Amount of precipitate getting peptised
5-6 c.c.	0.8 c.c.	Nothing
4-5 c.c.	No settling occurred on centrifuging	Practically whole

With this concentration of the sol, no rings developed with K_2SO_4 as the coagula were in gel state and did not settle after 24 hours. The coagulum obtained by the electrolyte at its precipitating concentration passed again in sol condition on vigorous shaking and no settling occurred on centrifuging. Nearly whole of the precipitate got peptised.

Table II

Sol containing 0.0396 gm. atom of Fe per litre.
 9 c.c. of the suspension contain 0.000178 gm. atom of Fe.

Amount of N/40 K_2SO_4	Volume of coagulum	Amount of precipitate getting peptised
3.5-4.5 c.c.	0.5 c.c.	Nothing
3.0 c.c.	Did not settle	Practically whole

With this concentration of the sol, quite prominent rings developed with potassium sulphate (Plate I). On shaking the tubes thoroughly rings appeared again when left undisturbed, but not of the same prominence as before.

Table III

Sol containing 0.0198 gm. atom of Fe per litre.
 9 c.c. of the suspension contain 0.000089 gm. atom of Fe.

Amount of N/40 K_2SO_4	Volume of coagulum	Amount of precipitate getting peptised
2-3 c.c.	0.3 c.c.	Nothing
1.5 c.c.	Did not settle	Practically whole

With this concentration of the sol, the coagula settled in compact forms without developing any rings.

SPEED OF COAGULATION

It had not been possible to follow the speed of coagulation of the sol with K_2SO_4 near its precipitating concentration, though slow coagulation occurred, because all the coagula passed again in sol state on vigorous shaking and hardly any settling of the coagula took place. Higher concentration of the electrolyte produced almost instantaneous coagulation.

The original sol was further purified by cold dialysis for 5 days. It contained 0.173 gm. atom of Fe per litre and its purity was 2.78. It was diluted to 0.0516 gm. atom and 0.0344 gm. atom of Fe per litre respectively.

Table IV

Sol containing 0.0516 gm. atom of Fe per litre.
 9 c.c. of the suspension contain 0.000232 gm. atom of Fe.

Amount of electrolyte	Volume of coagulum	Amount of precipitate getting peptised
(N/2 KCl)		
7 c.c.	0.6 c.c.	0.000045 gm. atom
6 c.c.	0.7 c.c.	0.000054 gm. atom
5 c.c.	0.7 c.c.	0.000068 gm. atom
4 c.c.	Did not settle	Practically whole
(N/40 K ₂ SO ₄)		
3.5—5 c.c.	0.8 c.c.	Nothing

With this concentration of the sol, there was distinct tendency for the formation of rings by coagulation with KCl, but due to the gel state of the medium the rings could not develop well. No rings developed with K₂SO₄ as it produced almost instantaneous coagulation of the sol. The tendency of the coagulum to return to the sol state, with K₂SO₄ as coagulant, disappeared with this purity of the sol.

Table V

Sol containing 0.0344 gm. atom of Fe per litre.
 9 c.c. of the suspension contain 0.0001548 gm. atom of Fe.

Amount of electrolyte	Volume of coagulum	Amount of precipitate getting peptised
(N/2 KCl)		
6 c.c.	0.5 c.c.	0.000045 gm. atom
5 c.c.	0.5 c.c.	0.000054 gm. atom
4 c.c.	0.5 c.c.	0.000081 gm. atom
3 c.c.	Did not settle	Practically whole
(N/40 K ₂ SO ₄)		
2—4 c.c.	0.6 c.c.	Nothing

With this concentration of the sol, quite prominent rings developed with KCl. There was tendency of the coagulum to return to sol state with KCl as coagulant and the peptised coagulum again settled periodically. K₂SO₄ produced instantaneous coagulation of the sol with no developed rings.

SPEED OF COAGULATION

K_2SO_4 produced almost instantaneous coagulation of the sol and hence the speed of coagulation was too quick to be followed. KCl , however, produced slow coagulation but, due to the reversible tendency of the coagulum with this electrolyte at its precipitating concentration, hardly any settling of the coagulum took place on centrifuging.

The original sol was further purified by cold dialysis for 7 days. It contained 0.180 gm. atom of Fe per litre and its purity was 5.62. It was diluted to 0.018 gm. atom of Fe per litre.

Table VI

Sol containing 0.018 gm. atom of Fe per litre.

9 c.c. of the suspension contain 0.000081 gm. atom of Fe

Amount of electrolyte (N/4 KCl)	Volume of coagulum	Amount of precipitate getting peptised
5 c.c.	0.5 c.c.	0.000036 gm. atom
4 c.c.	Did not settle	Practically whole
(N/40 K_2SO_4)	0.5 c.c.	Nothing
1—2 c.c.		

With this concentration of the sol, the coagula were all in transparent gel state by coagulating with KCl with one or two rings at the top. K_2SO_4 produced instantaneous coagulation of the sol.

ADSORPTION OF SOL

Table VII

Sol of Purity 1.05

Amount of the precipitate taken each time—0.684 gm. of Fe

Amount of the sol taken each time—0.021 gm. of Fe

Amount of N/40 K_2SO_4	Amount of Fe left in sol state	% Adsorption
0 c.c.	0.0418 gm.	—100
3 c.c.	0.028 gm.	—36
5 c.c.	0.016 gm.	22.3
7 c.c.	0.008 gm.	98.0
9 c.c.	0.000 gm.	100.0

In absence of the precipitate, the same amount of the sol required 3.2 c.c. of the electrolyte for partial and 5.0 c.c. for complete coagulation.

Table VIII

Sol of Purity 3.0

Amount of the precipitate taken each time—0.684 gm. of Fe

Amount of the sol taken each time—0.073 gm. of Fe

Amount of N/2 KCl	Amount of Fe left in sol state	% Adsorption
0 c.c.	0.103 gm.	—41.87
1 c.c.	0.000 gm.	100.00

In absence of the precipitate, the same amount of the sol required 7.0 c.c. of the electrolyte for partial and 11.0 c.c. for complete coagulation.

Table IX

Sol of Purity 3.0

Amount of the precipitate taken each time—0.684 gm. of Fe

Amount of the sol taken each time—0.073 gm. of Fe

Amount of N/40 K_2SO_4	Amount of Fe left in sol state	% Adsorption
0 c.c.	0.144 gm.	—57.02
1 c.c.	0.112 gm.	—54.27
3 c.c.	0.094 gm.	—29.47
5 c.c.	0.061 gm.	16.00
7 c.c.	0.015 gm.	79.84
9 c.c.	0.000 gm.	100.00

In absence of the precipitate, the same amount of the sol required 8.0 c.c. of the electrolyte for partial and 8.6 c.c. for complete coagulation.

Table X

Sol of Purity 5.42

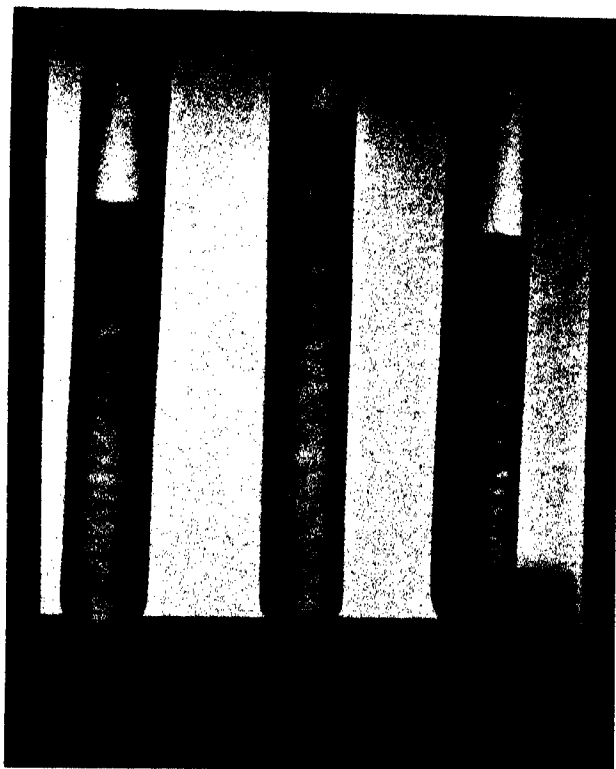
Amount of the precipitate taken each time—0.342 gm. of Fe

Amount of the sol taken each time—0.0363 gm. of Fe

Amount of N/4 KCl	Amount of Fe left in sol state	% Adsorption
0 c.c.	0.045 gm.	—24.00
1 c.c.	0.000 gm.	100.00

PLATE I

R. N. MITTRA—*Ferric Borate sol*



Periodic precipitate of ferric borate sol.

In absence of the precipitate, the same amount of the sol required 8.5 c.c. of the electrolyte for partial and 13.0 c.c. for complete coagulation.

The above results show that ferric borate sol produces rings on coagulation with bivalent coagulating ions from K_2SO_4 in impure stages. The speed of coagulation with this electrolyte is also slow at its precipitating concentration; but the reversibility of coagulum to sol state on shaking, as in centrifuging, hinders to study this speed at the precipitating concentration of the electrolyte and to find the optimum volume of the coagulum which settles periodically. From the tables on coagulation it is seen that the optimum volume has a tendency to have the value of 0.5 c.c. (*cf.* Tables II, V and VI), where rings appear. The same phenomenon is also observed when the sol is coagulated with KCl. Higher concentrations of the electrolytes coagulate the sol fairly rapidly and the reversibility of coagulum to sol state also disappears.

The peptised coagulum, which has already settled periodically with KCl or K_2SO_4 as coagulants, again settles periodically when left undisturbed (*cf.* Tables II and V). This is in accordance with the theory of adsorption of sol by its own precipitate. The bigger aggregates of coagulum adsorb the sol or the freshly formed primary particles obtained from the sol on coagulation. But from the data on the adsorption of sol by the precipitate of the same substance, it is seen that there is no adsorption of sol by a fresh precipitate of the same substance in presence of K_2SO_4 , while in presence of KCl there is sufficient adsorption, whether rings appear or not.

It may be concluded, therefore, that the speed of coagulation of sol and the nature of coagulum are the guiding factors in the process of the formation of periodic precipitate in sols, the third factor, *viz.*, the adsorption of sol being a general phenomenon in colloids.

CHANGES IN THE VISCOSITY OF AGAR SOL WITH CONCENTRATION

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Received December 12, 1939

SUMMARY

In a previous paper we have studied the changes in the viscosity of agar sols with ageing and have shown that it is more due to a certain orientation of colloid particles than their hydration. In the present communication we shall give our results on the effect of sowing with gel and the concentration of agar sols on their viscosities.

To 1.04 per cent agar sol a tiny piece of agar gel of the same concentration was added and the sol was kept in a thermostat for 6 to 8 minutes and the unmelted gel piece was then removed. The viscosity of this sown sol with already formed gel was determined. The experimental results with ordinary agar sol and the sol sown with gel piece of the same concentration are given below :—

Temperature	Viscosity ordinary sol	Viscosity on sowing
50°C	0.01326	0.02180
40°C	0.01758	0.03745

The experimental results show that sowing a sol of agar with an already formed gel remarkably increased the viscosity of the agar sol, the change being more pronounced at 40°C than at 50°C.

In the following table, the results on the viscosity of agar sols of various concentration for different temperatures are reproduced :—

Concentration		Viscosity at				
% agar	65°C	60°C	55°C	50°C	45°C	40°C
0.27	-	0.00598	0.00657	0.00724	0.00800	0.00890
0.47	-	0.00732	0.00788	0.00871	0.00965	0.01098
1.04	0.00959	0.01042	0.01152	0.01326	0.01542	0.01758
1.73	0.01592	0.01746	0.02000	0.02296	0.02789	-
2.99	0.03342	0.03756	0.04312	0.04885.	-	-

These results when plotted (viscosity-concentration) show that the figures are curvilinear as has been found to be general with lyophilic sols like gelatin, soap, night blue, etc. At higher concentration, the increase in the viscosity is very steep. When, however, temperature increases, the curve becomes less steep and has a tendency to approach a straight line. Similar results were obtained by Biltz and Steiner on the viscosity of the sols of night blue of various concentrations for different temperatures.

There are various formulæ for expressing the viscosity concentration curves suggested by several investigators. Hess obtained the formula $\eta_r = \frac{\eta_s}{1 - a\phi}$ where η_r is the viscosity of the sol, η_s the viscosity of water or dispersing medium, ϕ the total volume of dry solid per unit volumes of the sol, and 'a' is a factor greater than unity so that $a\phi$ represents the actual volume of the colloid particles due to their high hydration per unit volume of the sol. On calculating the values of 'a,' which gives the idea regarding the hydration, we find that they are different for the various concentrations of agar sols. The value of 'a' increases with the increasing concentration of agar. For example, with 1.73% agar sol the value of 'a' falls to about half of what it is with 0.27% agar sol. Similar variation of the value of 'a' was found by Hess with a sol of red blood corpuscles. It may be assumed that this variation in the value of 'a' is due to increased hydration for smaller concentrations of suspensions, 'a' decreased as the concentration of the dispersed phase is increased. The solvation or hydration of a colloid particle is undoubtedly guided by the phenomena of adsorption. It is, therefore, obvious that for agar sols of concentrations, say, 0.27% and 1.73%, the mass of water present is very high in comparison to the amount of solid agar present. We are, therefore, of opinion that there should not be much difference in the hydration of agar colloid particles when the concentration changes from 0.27% to 1.73%.

We have also investigated the applicability of the formula developed by Hatschek for the viscosity of lyophilic colloids, viz., $\phi = \left(\frac{\eta_1}{\eta_1 - 1} \right)^3$, where $\eta_1 = \frac{\eta_r}{\eta_s}$ and ϕ is the ratio of the total volume of the system to the total volume of the dispersed phase. Hatschek calculates the solvation or hydration of the suspended particles from the volume of ϕ . If ϕ' is the total volume divided by the dispersed weight, the H or the volume occupied by unit weight of dispersed phase after hydration is given by the ratio $\frac{\phi'}{\phi}$. Calculating the solvation of dispersed agar, we find the value of ϕ'/ϕ is not constant but steadily increases with the increasing concentration of the sol. This result is contrary to what we obtained as solvation for agar colloid particles from the formula of Hess.

Hatschek concludes that the value of H should remain constant and he has shown this within small range of concentrations of protein sols of sodium

caseinate, euo-globulin and pseudo-globulin. Our results for H obtained from the viscosity of agar sols, however, definitely show that the solvation is not constant and the variance is very remarkable. Similar results are obtained by D' Errico and Botazzi for glycogen sols, Chick and Martin for casein sols and Bogue for gelatin sols.

The value of 'H' calculated from the formula of Hatschek for agar sol is very high. For example, at 50°C the value of 'H' is about 16 for 1.73% agar sol and hence it is apparent, a colloidal particle adsorbs a volume of water about 16 times the volume of the solid colloidal agar. This leads, therefore, to the conclusion that a colloid particle is wrapped with a layer of water molecules several hundred molecules deep. From our ordinary conceptions of the phenomena of adsorption this value seems to be very high. Arrhenius also very adversely criticised the formula of Hatschek on the ground that the hydration comes out to be improbably high.

Arrhenius suggests his empirical formula for solutions in the case of sols as $\log \eta = \phi c$ where ϕ is a constant and 'c' represents the concentration. Chick and collaborators find this formula to be applicable in the case of some protein sols. We find that the curves obtained by plotting logarithms of the viscosity of agar sols as ordinates and the concentrations as abscissae are not straight lines. Further, calculating the hydration factor 'η' from the formula $\log \eta = \phi \frac{100p}{100 - (\eta + 1)p}$ where 'p' is the weight of dry substance dispersed per 100 c.c. of the sol, comes out to be negative.

It appears, therefore, that the various formulæ relating concentration with the viscosity are not applicable in the case of agar sols and the enormous increase in the viscosity produced by small concentrations by weight of dispersed material of lyophilic colloids is found to be difficult to explain by a single formula. All theoretical treatments regarding the viscosity of lyophilic sols are based on the assumption that the dispersed phase is highly hydrated, so that the colloid particles occupy a very large space in comparison to the volume calculated from the weight and the concentration and density. We have, however, shown that the solvation of colloid particles, as calculated from the above assumption, leads to very high and irregular hydration values, and hence the formula of Hess and Hatschek seems to be not correct in expressing the viscosity and concentration relation of lyophilic colloids. Moreover, it must be pointed out here that one is not yet certain whether the viscosity of several lyophilic colloids as measured by various kinds of apparatus is true or not as in most cases of highly viscous sols it is remarkably dependent on the rate of sheer and the method of measurement. This is not known in the case of liquids. In recent years, a large amount of work has been done with lyophilic sols and it has been observed that in most cases, the Pouseuill's law, *viz.*, rate of flow is proportional to sheering force,

is not followed. It is found that as the rate of sheer is increased, the viscosity of the sol rapidly decreases.

McBain considers the high viscosity of lyophilic colloids as due to the particles of the dispersed phase arranging themselves in long threads or loose ramifying aggregates. Similarly Ostwald considers the appearance of 'structures' in some sols which are of lyophilic nature.

We have already reported in a previous paper that the viscosity of agar sols at different temperatures can be explained from the view that the colloidal particles of agar are in orientated condition and that the sols possess a distinct rigidity. We are of opinion that the remarkable increase in the viscosity of the dispersing medium with the increasing concentration of the sol is due to the increase in the rigidity as well as the relaxation time 'T' with the increasing concentration of the sol. Unless more experimental data are available on the rigidity and the relaxation time of agar sols of various concentrations an attempt to obtain a formula connecting viscosity and concentration seems not to be possible.

It must be emphasized, here, that a high solvation of agar colloid particles cannot explain the rapid increase in the viscosity of the agar sols with increasing concentration as the degree of hydration is practically constant for an agar sol of either 0.27% or 3% concentration.

CONCLUSION

The effects of sowing with an already formed gel and of concentration on the viscosity of agar sols have been studied here.

The experimental results show that sowing a sol of agar with an already formed gel remarkably increases the viscosity of agar sols, the change being more pronounced at lower temperatures than at higher ones. In this respect, its behaviour is similar to the sols of gelatin, soap etc.

The effect of sowing has been explained from the point of view of a 'definite orientation' in the colloidal particle.

The results with concentrations show that the viscosity-concentration relation is curvilinear like those of other lyophilic sols but with increase of temperature, the curve has a tendency to approach a straight line.

Various formulæ expressing the viscosity-concentration relation (those given out by Hess, Hatschek and Arrhenius separately) have been discussed and have been shown to be not applicable to agar sols.

Views put forward by McBain and Ostwald on the high viscosity of lyophilic colloids have been discussed.

It is emphasized that a high solvation of agar colloidal particles cannot explain the rapid increase in the viscosity of the agar sols with the increase of concentration. This can be explained as due to the increase in the rigidity as well as the relaxation time 'T' with the increasing concentration of the sol.

CHANGES IN THE VISCOSITY OF AGAR SOL WITH TEMPERATURE

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SUMMARY

The change in the viscosity of agar sols at different temperatures has been studied. Our experimental results show that agar sols do not show marked change in their viscosities and hence the process of aggregation for this sol is very slow with ageing. From the high temperature coefficient of the viscosities of agar sols, it has been concluded that high viscosities of agar sols are due mainly to a certain orientation of the colloidal micelle imparting a rigidity to the sols. The viscosity values have been calculated from Madge's equation and it has been found that there is a close agreement.

In a previous publication we have studied the gelation of soaps in alcoholic solutions, and have shown that the phenomenon closely resembles the separation of a solid from a supersaturated solution. Similar conclusions have been drawn from our study¹ of the sol-gel transformation of gelatin and agar sols. From a study of the changes in viscosity of gelatin sols near the gelation temperature it has been concluded that gelatin solutions at higher temperatures contain extremely fine particles of molecular dimension which gradually polymerise to bigger aggregates on cooling the sols, and in gelations, as observed in the reversible sol-gel transformations, an aggregation of simple molecules is an inevitable consequence. In this paper we have studied the change in the viscosity of agar sols at different temperatures.

Kahlbaum's pure agar was dissolved in water and reprecipitated with alcohol. The precipitate was dried over water bath and the sols of desired concentrations were prepared by dissolving the weighed solid in water kept in a bath maintained at 75°C–80°C. The sol thus prepared contained some flakes which were removed by filtration and the exact concentration of the sol was determined by evaporating a known volume of sol over a water bath in a platinum crucible. Sols of agar as prepared by us gave concordant and reliable viscosity readings at the temperatures investigated in this paper.

Agar sols of various concentrations were first kept at a temperature of 80°C and then a measured volume of the sol was introduced in Ostwald's viscometer placed in a thermostat maintained at 60°C. Viscosity measurements were made at

different times in the course of one hour. Next, the temperature of the thermostat was lowered by 5°C and the measurements were taken at lower temperatures. The temperature of the thermostat was further lowered by steps of 5°C till small blocks of agar gel appeared and the determination of viscosity of the agar sols at different times became impossible. The results are recorded below.

Table I

Temperature.	Viscosity of 0.27% agar sol		Viscosity of 0.47% agar sol.	
	After 15 mins.	After 60 mins.	After 15 mins.	After 60 mins.
60°C	0.00598	0.00598	0.00732	0.00732
55°C	0.00657	0.00657	0.00788	0.00788
50°C	0.00724	0.00724	0.00871	0.00871
45°C	0.00799	0.00799	0.00965	0.00965
40°C	0.00885	0.00885	0.01140	0.01140

Table II

Temperature.	Viscosity of 1.04% agar sol		Viscosity of 1.73% agar sol		Viscosity of 2.99% agar sol	
	After 15	After 60	After 15	After 60	After 15	After 60
	mins.	mins.	mins.	mins.	mins.	mins.
65°C	0.00959	0.00960	0.01573	0.01573	...	..
60°C	0.01042	0.01045	0.01749	0.01749	...	..
55°C	0.01152	0.01157	0.02006	0.02006	...	...
50°C	0.01326	0.01332	0.02296	0.02305	0.04885	0.04908
45°C	0.01542	0.01550	0.02789	0.02814	Sets	Sets
40°C	0.01758	0.01769	Sets	Sets	„	„

It will be seen from our experimental results that unlike gelatin sols, agar sols do not show a marked change in the viscosity with time during the period of one hour even at temperatures near their setting points. When, however, concentrated sols (Table II) are used, the viscosity increases with time and this is marked at low temperatures. We have already remarked in a previous publication that the increase in the viscosity as observed with a sol of gelatin with time is due to an increase of aggregation or orientation of colloid particles with age. As there is no remarkable change in the viscosity of agar sols within an hour's time, we are of opinion that the process of aggregation or orientation of colloid particles with the ageing of the sol is very slow. Similar conclusion has been arrived at from our study on the hysteresis of sol gel transformation of agar sols.

TEMPERATURE COEFFICIENT OF THE VISCOSITIES OF AGAR SOLS

In the following table the temperature coefficients per 5°C of viscosities of agar sol for various ranges of temperature are calculated :

Table III

Temperature coefficients

	$60^{\circ}\text{C} - 55^{\circ}\text{C}$	$55^{\circ}\text{C} - 50^{\circ}\text{C}$	$50^{\circ}\text{C} - 45^{\circ}\text{C}$	$45^{\circ}\text{C} - 40^{\circ}\text{C}$
0.27% sol	0.00059	0.00067	0.00075	0.00086
0.47% sol	0.00056	0.00083	0.00124	0.00170
1.04% sol	0.00110	0.00174	0.00216	0.00216
1.73% sol	0.00254	0.00296	0.00493	...

The above table shows that the temperature coefficient of viscosities of agar sols is very high for concentrated sols and it rapidly increases with the lowering of the temperature.

The idea of an orientation and association of molecules in the case of pure liquids affecting their viscosity has been developed by several workers. Maxwell showed that the viscosity $\eta = Et$, where E is the modulus of elasticity and t is the relaxation time (*i.e.*, the time in which the stress has decreased to $1/e$ th of its value). Hence it is apparent that there is a rigidity in the liquids and the orientation theory of viscosity of liquids is not contradictory to the original ideas of Maxwell. In mobile fluids t is a very small fraction of a second, and E is not easily determined by experiments.

The rigidity in the case of lyophilic colloids has been found to exist in measureable amounts by several investigators. We are of opinion that this distinct rigidity observed in highly viscous lyophilic sols is due to a certain orientation of the colloidal micelle originating from the forces which are inherent on the solid surface to form bigger aggregates. High hydration of colloid particles, however, checks the actual aggregation. The force which causes this orientation of colloid particles of the sol is also of a smaller magnitude and hence the rigidity is not high and the sol for a particular shearing force behaves as a liquid. In the case of reversible sol-gel substances like agar, gelatin, soap, etc., we have already pointed out that the tendency of aggregation rapidly increases with lowering of temperature and the rigidity, and hence the viscosity increases remarkably at lower temperatures.

Madge shows that the rigidity modulus with temperature T for a liquid varies as given by $E = Ae^{\beta T}$ where β and A are constants. Similarly, Madge concludes that time t can be represented by $t = M/(T-b)$, where M is a constant, and b is the temperature of complete solidification of the liquid where the relaxation time becomes infinitely large. Combining these two values for the rigidity and the

relaxation time, the formula for the viscosity according to the view of Maxwell appears as

$$N = Ae^{\beta\tau/\tau-b} \dots \dots \dots (1)$$

In the following table, the viscosity of agar sol for different temperatures have been calculated from the above formula.

Table IV

($\beta=0.003$,
 $A=0.1386$,
 $b=281$)

Concentration of agar sol—0.47%

Temperature	Calculated Viscosity	Observed
60°C	0.00722	0.00732
55°C	0.00786	0.00788
50°C	0.00868	0.00871
45°C	0.00970	0.00965
40°C	0.01105	0.01098

Table V

($\beta=0.003$,
 $A=0.1742$,
 $b=288$)

Concentration of agar sol—1.04%

Temperature	Calculated Viscosity	Observed
65°C	0.00958	0.00959
60°C	0.01048	0.01042
55°C	0.01162	0.01152
50°C	0.01308	0.01326
45°C	0.01505	0.01452
40°C	0.01778	0.01758

Table VI

($\beta=0.003$,
 $A=0.2369$,
 $b=296$)

Concentration of agar sol—1.73%

Temperature	Calculated Viscosity	Observed
65°C	0.01562	0.01572
60°C	0.01758	0.01746
55°C	0.02002	0.02000
50°C	0.02337	0.02296
45°C	0.02826	0.02789

Table VII

$$(\beta = 0.003,$$

$$A = 0.4556,$$

$$b = 300)$$

Concentration of agar sol—2.99%		
Temperature	Viscosity calculated	Observed
65°C	0.03349	0.03342
60°C	0.03798	0.03756
55°C	0.04409	0.04312

The equation (1), connecting the viscosity of a sol like that of agar and temperature, has been found to be in close agreement with our observed results. Similar conclusion is arrived at from the measurements of viscosities of gelatin sols of various concentrations as will be evident from the following tables:—

Table VIII

$$(\beta = 0.03,$$

$$A = 0.00002347,$$

$$b = 288)$$

Concentration of gelatin sol—2%		
Temperature	Viscosity calculated	Observed
45°C	0.01088	0.01088
40°C	0.01124	0.01129
35°C	0.01210	0.01239
30°C	0.01387	0.01339
25°C	0.01791	0.01780

Table IX

$$(\beta = 0.03,$$

$$A = 0.00009218,$$

$$b = 301.)$$

Concentration of gelatin sol—10%		
Temperature	Viscosity calculated	Observed
50°C	0.06770	0.06770
45°C	0.07540	0.07585
40°C	0.09192	0.09302

The above results show that in the case of gelatin also, β remains constant and A increases with the increasing concentration of the sol as in the case of agar

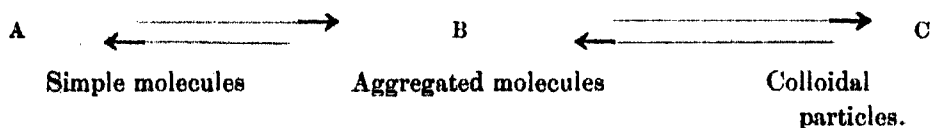
sol and that there is a remarkable agreement between the observed and calculated values of the viscosity.

It will also be seen from the above that the value of b or the temperature for complete solidification of a gel is always less than their actual setting temperatures. Thus, 0.47% of agar sol sets to a firm gel at a temperature of 30°C whilst the value of b comes out to be 8°C for this concentration. It is well known that we generally take the setting temperature of a sol when it sets to a gel that can stand with the gravitational force on turning the test-tube containing the gel up side down. Hence it is obvious that the temperature for complete solidification is much lower than the temperature of setting of a sol. It may be of interest to note that Madge similarly obtains the values of b of different liquids much less than their freezing points.

We have shown in this paper that there exists some rigidity in agar sols which can suitably explain the influence of temperature on the viscosity of agar sols. We are of opinion that this rigidity occurs due to the orientation of colloidal particles originating from a force similar in nature as inherent in solid materials, viz., "crystallographic force." This view is further confirmed from our observations on the effect of sowing a sol of agar with already formed gel, which is reported in a subsequent paper.

It has already been emphasized in previous publications,^{1,2} that the sols of silicic, vanadic, tungstic, molybdic and antimonie acids contain sufficient quantities of these substances in the molecular condition, simple and aggregated together with the colloidal particles. The simple molecules have a general tendency to aggregate and gradually merge into particles of colloidal dimension with age. Raising the temperature of a sol, like that of agar or gelatin when freshly prepared, causes the disintegration of the colloidal particles and aggregated molecules into simpler ones.

This is supported by the ultramicroscopic observations on protein sols by Arisz and by Bechmann. We are of the opinion that as in gelatin sols, so also in agar sols the following equilibrium exists :



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NEW BLOOD FLUKES OF THE FAMILY SPIRORCHIDAE STUNKARD (TREMATODA) FROM THE MARINE TURTLE *CHELONE MYDAS* OF THE ARABIAN SEA WITH OBSERVATIONS ON THE SYN- ONYMY OF CERTAIN GENERA AND CLASSIFICATION OF THE FAMILY.

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SUMMARY

The new blood flukes, one belonging to a new species of the genus *Learedius* and the other to a new genus *Monticellius*, are described. Synonymy of the genus *Gomtiotrema* Sinha with *Plasmiorchis* Mehra is discussed, and the latter name is accepted on the basis of priority. A new genus *Hemiorchis* is proposed for *Plasmiorchis hardellii* Mehra.

The importance of the presence of one or two suckers in the classification of the family Spirorchidae is discussed, and it is held that the monostomes are of polyphyletic origin. The genera *Amphiorchis* Price, *Learedius* Price, *Neospiroorchis* Price and *Monticellius* n. g. are assigned to their respective sub-families.

We described in 1933 and 1934 the blood flukes of the fresh water turtles available at Allahabad, discussed the relationships of the families of blood flukes and gave a revised classification of Spirorchidae. Previous work on this family was reviewed in these papers. Sinha, in 1934, described a new genus *Gomtiotrema*, which, as will be shown subsequently, is held synonymous with *Plasmiorchis* Mehra, 1934. The latter name has been accepted on the basis of priority.

Price (1934) described four new species of blood flukes belonging to three new genera *Neospiroorchis*, *Amphiorchis*, and *Learedius*, obtained from a marine turtle, *Chelone mydas*, which died in the National Zoological Park, Washington. He also reviewed the literature concerning *Distoma constrictum* Leared, 1862, proposing

the new name *Learedius europaeus* for this species. The form described by Monticelli as *Mesogonimus constrictus*, for which Looss (1899) had proposed the genus *Hapalotrema*, he designates as *Hapalotrema mistroides* (Monticelli, 1896), considering it to be the type of the genus. For the form described by Looss he has created a new species, *Hapalotrema Loossi* (syn. *Hapalotrema constrictum* (Leared) of Looss, 1899).

In the present paper there are described two new blood flukes obtained from *Chelone mydas* of the Arabian sea, caught near the Kiamari coast at Karachi. One of these forms belongs to a new species of the genus *Learedius* Price, 1934, and the other along with *Learedius similis* Price, 1934, to a new genus *Monticellius*. In the discussion on the classification of the family it is shown that the genera *Learedius* Price and *Monticellius* n.g. should be included in the sub-family *Spirorchinae* Stunkard, *Amphiorchis* in the sub-family *Hapalotrematinae* Stunkard, and *Neospororchis* in the sub-family *Unicaeciinae* Mehra.

LEAREDIIUS ORIENTALIS, NOV. SPEC. (figs. 1, 2 and 3)

Two dozen specimens were obtained from the ventricle and auricles of the heart of one adult female marine turtle *Chelone mydas* caught from the Arabian Sea, near the Kiamari coast, Karachi. The blood flukes came out as soon as the heart was opened in salt solution and moved slowly with gliding movements. The body is thin, transparent, dorso-ventrally flattened, elongated, somewhat elliptical and constricted at about the middle or just in front in the region of the acetabulum, measuring on the average 4—5.5 mm. in length and 1.32—1.36 mm. in maximum breadth, which lies in the region of the intestinal bifurcation and in the testicular region at about one-third of its length from the acetabulum to the ovary. In some specimens, however, the maximum breadth lies only just behind the acetabulum. The anterior end is broad and somewhat rounded, and the posterior end narrow and bluntly pointed. The cuticle is provided with minute backwardly directed spines, which hardly project outside the body wall. The oral sucker is sub-terminal, longer than broad and slightly protrusible, measuring 0.32—0.35 mm. in length and 0.256—0.32 in maximum breadth. In two specimens the oral sucker appeared circular, and measured 0.224 and 0.26 mm. in diameter. The acetabulum is thin, somewhat membranous, rounded usually with folded margins and peduncled, measuring 0.4—0.56 mm. in diameter. It lies a little in front of or at about the middle of the body length; its inner surface surrounding the cavity is covered with minute denticle-like projections or spines, which resemble those of the body wall. The pharynx is absent. The oesophagus, narrow at its origin from the oral sucker, widens gradually in the first third or half of its course. It is long and slightly tortuous with three or four bends, measuring 1.12—1.84 mm. in length and 0.08—0.128 mm. in breadth. The deeply staining gland cells surrounding it are specially numerous.

around its posterior part, where they form a compact mass. The intestinal caeca turn forwards as soon as they arise and then bend backwards forming the charac-

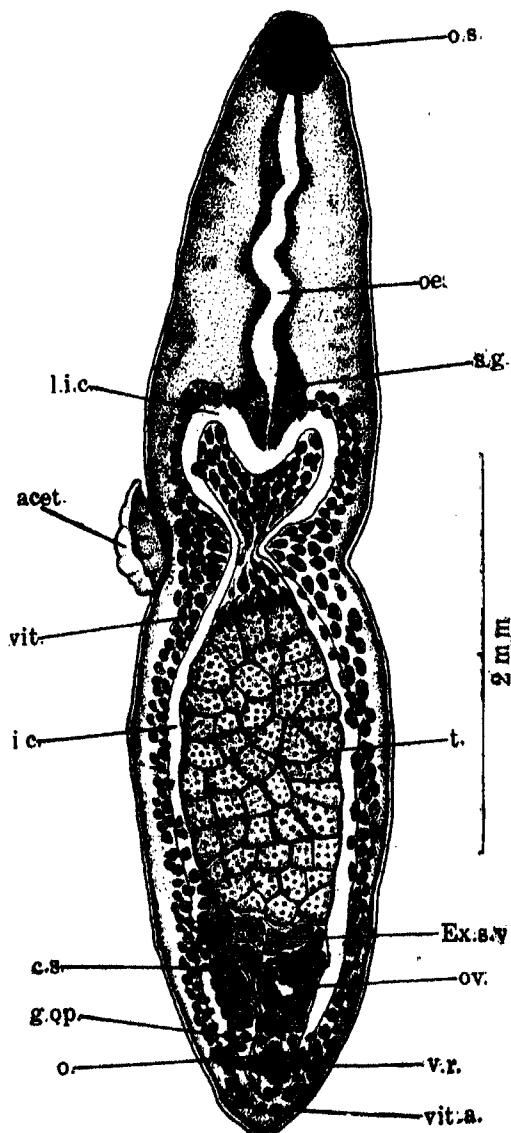


Fig. 1

Learedius orientalis n. sp. Dorsal view.

Acet., acetabulum; *c. s.*, cirrus sac; *ex. b.*, excretory bladder; *ex. s. v.*, external seminal vesicle; *g. op.*, genital opening; *i. c.*, intestinal caecum; *l. i. c.*, loop of intestinal caecum; *o.*, ovum; *oes.*, oesophagus; *ov.*, ovary; *o. s.*, oral sucker; *s. g.*, salivary gland cells; *t.*, testes; *vit.*, vitellaria; *vit. a.*, vitelline arc; *v. r.*, vitelline reservoir.

teristic short wide loops, one on each side of the posterior part of the oesophagus. They curve inwards in the region of the acetabulum coming near one another and then diverge outwards to continue their lateral course, pressed closely outside the testes and ovary, terminating a little in front of the hinder end, where they become very narrow and pass mesially forming an arc though remaining quite separate. They may touch one another at their blind ends, but they are not united to continue into one another; the terminal ends of the vitellaria surrounding them here are, however, united into a complete arc. The caeca are fairly broad, slightly narrower than the widest part of the oesophagus and not slender as in *Learedius learedi* Price, except at their blind ends. They may be indented at their inner margins, where they are pressed in between the outermost testes. The excretory opening is sub-terminal and dorsal. The short excretory bladder is situated between the blind ends of the caeca; it is V-shaped rather than Y-shaped with the cornua much longer than the main stem.

The genital opening lies ventrally, slightly to the left side of the median line, in level with or just behind the posterior margin of the ovary, at 0.44—0.52 mm. distance from the hinder end of the body. The testes, 35—45 in number (28 in one specimen), lie closely crowded and pressed against one another irregularly in a large mass, filling the intercaecal space between the acetabulum and external seminal vesicle. They are so much pressed against the caeca that the latter present a crenated appearance on their inner walls. They have varying sizes and shapes, usually polyhedral, rectangular, squarish, or triangular, and measure 0.14×0.16 , 0.176×0.208 , 0.288×0.112 , 0.192×0.16 , 0.208×0.16 and 0.256×0.24 . The external seminal vesicle is large, thin-walled, transversely elongated and filled with sperms. It is situated immediately behind the testes mass, between the latter and the ovary, to the right side of the basal part of the cirrus sac, measuring 0.35—0.48 mm. in length and 0.096—0.16 mm. in maximum breadth. The cirrus sac, fairly large and with strongly developed musculature, 0.6—0.64 mm. in length and 0.096 mm. in maximum breadth near its base, extends from the genital opening on the left side of the median line to the hinder margin of the testes in level with or a little in front of the anterior border of the external seminal vesicle, overlapping the ovary dorsally. It is bent, somewhat retort-shaped or in the form of an elongated letter S with a deep curvature in the right margin of its broad dilated base, which is filled by the internal seminal vesicle of 0.12 mm. length and 0.045 mm. maximum breadth and well-developed *pars prostatica* surrounded by the numerous prostate gland cells. Its more or less straight and narrow tubular part contains the ejaculatory duct or cirrus, which was found partly protruded in one specimen.

The large, median, deeply lobed or somewhat dendritic ovary, $0.49—0.51 \times 0.53$ in size, occupies almost the entire intercaecal region between the external seminal vesicle and the genital opening at 0.48 mm. distance from the hinder end. In some

specimens it even overlaps the inner walls of the caeca and posterior margin of the external seminal vesicle. The *receptaculum seminis* is very small, 0.048–0.066 mm. in diameter, somewhat rounded and situated to the right side, inside the right caecum just or a little behind the ovary and, in some specimens, overlapped by the yolk reservoir. The oviduct, not distinctly seen in entire mounts, arises from the hinder margin of the ovary to the right side of the median line. The elongated ootype lies inside the *receptaculum seminis* partly or completely overlapped by the yolk reservoir, and bends forwards immediately in front of the posterior union of the

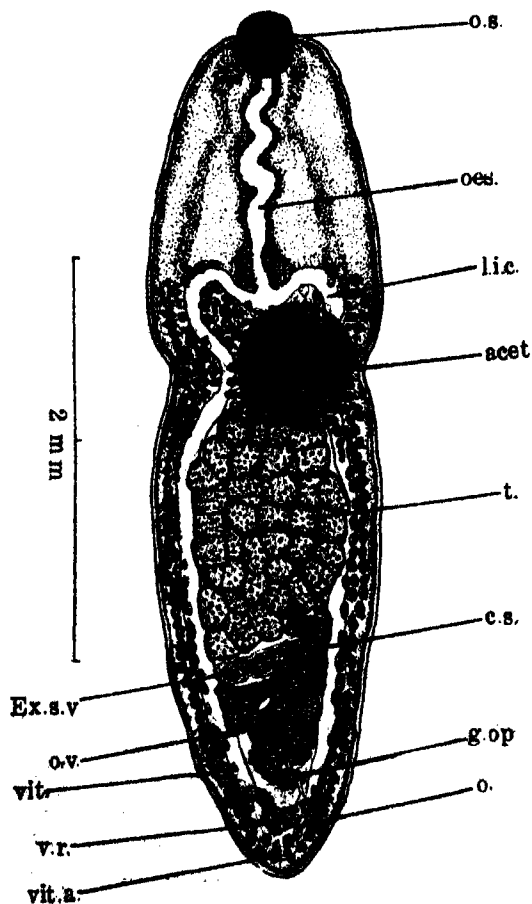


Fig. 2

Learedius orientalis n. sp. Ventral view.

(Lettering as in Fig. 1)

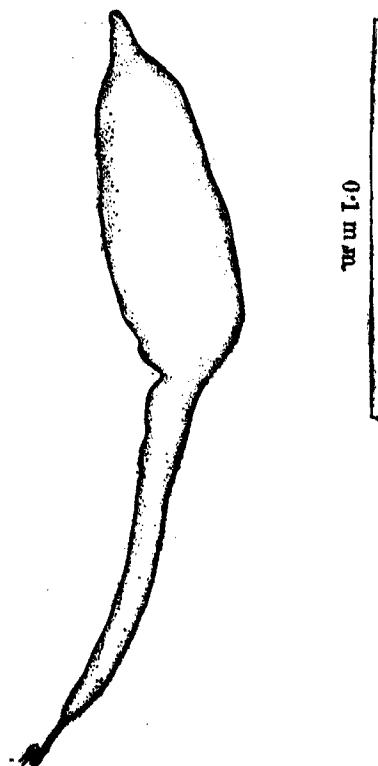


Fig. 3

Ovum of *L. orientalis* n. sp.

vitellaria to continue as the metraterm of 0.225–0.24 mm. length and 0.036 mm. breadth, which lies to the left side and is easily distinguished by the presence in it

of a single large ovum. The terminal part of the metraterm is surrounded by deeply staining parenchymatous cells. The shell gland cells are present, but the Laurer's canal is not distinctly seen. The vitellaria are composed of moderate sized follicles and mostly situated laterally outside the caeca, commencing a little in front of the intestinal bifurcation, *i.e.*, in the region surrounding the forwardly directed loops and terminating at the hinder end of the body just behind the blind ends of the caeca, where they are united to form the vitelline arc. The vitellaria are also united transversely just behind the intestinal bifurcation up to the hinder margin of the acetabulum filling the whole inter-caecal region in front of the testes and forming a transverse band across the body. They form, on account of their transverse union anteriorly and posteriorly, a complete circle surrounding the caeca and all the genital organs enclosed by the latter. The transverse vitelline ducts arise at or a little behind the posterior margin of the ovary and just in front of the caudal union of the vitellaria, the right a little ahead of the left one, and unite mesially to form the large conical yolk reservoir with the pointed end directed backwards. The ovum (fig. 3) is large and fusiform, and produced into polar prolongations at both ends, measuring 0.195—0.225 mm. in length including the prolongations and 0.021—0.024 mm. in maximum breadth. The posterior end of the ovum is prolonged into a long filament, which becomes very narrow at the end, while the anterior prolongation is, as a rule, a short conical process.

Learedius orientalis sp. n. differs from *Learedius learedi* Price in the larger size, especially the much greater breadth of the body, greater size of the two suckers, especially the acetabulum, larger number of testes, large size of the external seminal vesicle and the cirrus sac, which also differs in shape, posterior union of the vitellaria, and shape of the ovum.

Host: *Chelone mydas*.

Position: Ventricle of heart.

Locality: Arabian sea, near Karachi.

MONTICELLIUS INDICUM NOV. GEN., NOV. SPEC. (fig. 4)

Only one specimen of this blood fluke was obtained from the ventricle of the heart of the same *Chelone mydas*, from which the previous species is described. The body is thin, transparent, narrow and elongated, somewhat filamentous like a very small nematode, measuring 3 mm. in length and 0.4 mm. in maximum breadth which lies in the region of the testes. The breadth near the anterior and posterior ends is smallest, 0.208 mm. behind the oral sucker and 0.224 mm. just behind the ovary; immediately behind the acetabulum and in the region of the ovary it measures 0.32 mm. The cuticle appears to be devoid of spines or verrucae. The oral sucker, 0.144 mm. in length and 0.148 mm. in maximum breadth, is sub-terminal and protrusible. It is broader in front and narrow behind and thus appears to be produced into a

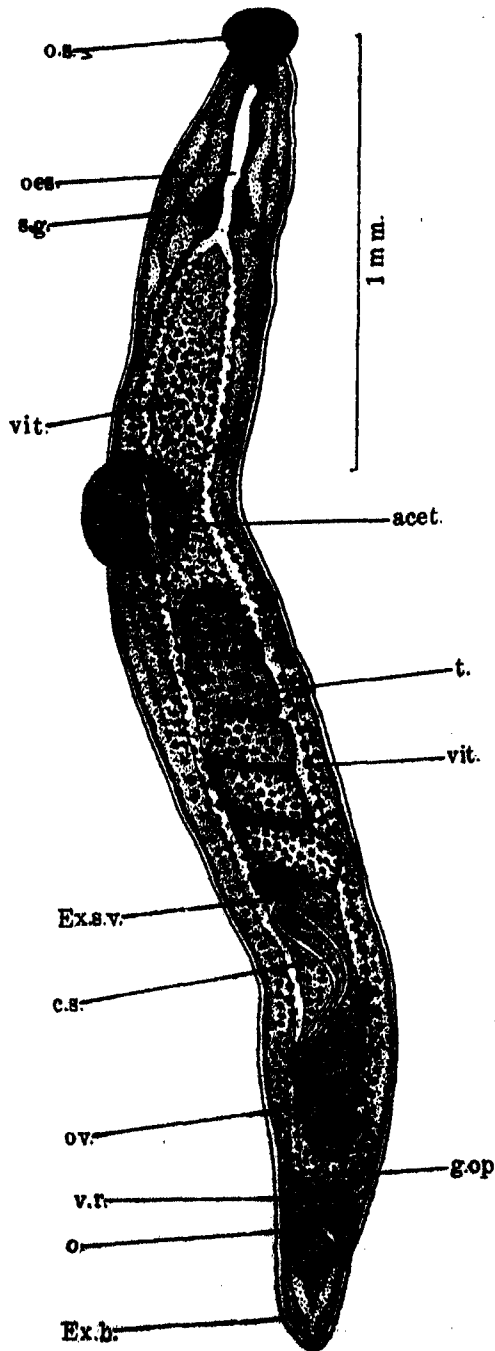


Fig. 4

Monticellius indicum n. g., n. sp. Dorsal view.

(Lettering as in Fig. 1)

small posterior prolongation. The acetabulum, 0.256 mm. in diameter, is nearly double the size of the oral sucker and pre-equatorial, situated 1.056 mm. behind the anterior end and 1.95 mm. in front of the hinder end. The pharynx is absent. The oesophagus, 0.24 mm. long and 0.03 mm. broad, is nearly straight and surrounded by the salivary gland cells which form a bulbiform mass around its hinder part. The intestinal bifurcation lies much in front of the acetabulum. The intestinal caeca pass downwards as soon as they arise, terminating a little distance in front of the hinder end; they do not form the anteriorly directed loops at their origin as in the genus *Learedius*. The excretory opening is sub-terminal, situated dorsally near the hinder end. The small excretory vesicle is V-shaped; the two cornua could be traced over only a small distance.

The testes, five in number with entire or irregular margins and 0.16—0.176 mm. in diameter, lie median, closely pressed against one another in a single linear series occupying almost the entire intercaecal space between the acetabulum and external seminal vesicle, much in front of the hinder end at 1.04 mm. distance from it. The external seminal vesicle, filled with sperms, is situated median in the intercaecal space, pressed between the hindmost testis and basal part of the cirrus sac, 0.91 mm. in front of the hinder end and 0.7 mm. behind the acetabulum. It is elliptical in shape and directed slantingly, measuring 0.19 mm. in length and 0.06—0.066 mm. in uniform breadth. The cirrus sac is long, somewhat sinuous, bent twice, or S-shaped, having 0.72 mm. length and 0.075 mm. greatest breadth which lies across its base. Its distal, tubular part after the first bend, which makes a right angle with the base, lies ventrally to the ovary, and suddenly narrows after the second bend to open to the exterior at the genital opening which lies almost median at 0.36 mm. distance from the hinder end. The large internal seminal vesicle fills the basal part of the cirrus sac and is followed by the tubular *pars prostatica* surrounded by the well developed prostate gland cells. The *ductus ejaculatorius* occupies the narrow terminal part of the cirrus sac which is about one-third of its entire length. The ovary is lobulated, but not dendritic, and situated ventrally to the tubular part of the cirrus sac at 0.39 mm. distance from the hinder end, measuring 0.4 mm. in length and 0.16 mm. in greatest breadth. The small *receptaculum seminis* lies just behind the ovary to the right side in front of the yolk reservoir. The oviduct arises from the right margin of the ovary at its posterior end. The shell gland mass surrounding the ootype lies partly below and partly behind the yolk reservoir. The Laurer's canal could not be observed. The metraterm, 0.27 mm. in length and 0.03 mm. in greatest breadth, lies somewhat transversely a little behind the yolk reservoir and contains a single ovum in its large proximal part. It opens by a narrow terminal duct to the exterior at the genital opening. The ovum is large with narrow, somewhat curved or hook-shaped prolongations at both ends, measuring 0.162 mm. in length including the prolongations and 0.021 mm. in greatest breadth. The

prolongation at one end is longer and narrower than at the other. The vitellaria are composed of small follicles and extend from the intestinal bifurcation to a little behind the ovary. They are laterally situated outside the intestinal caeca except in the pre-testicular region between the intestinal bifurcation and anterior testis, where they are united to form a large median mass filling the entire intercaecal field. Posteriorly, they unite to form the large yolk reservoir which occupies a median position immediately behind the genital opening at 0.18 mm. distance from the hinder end.

Host: *Chelone mydas*.

Position: Heart.

Locality: Arabian sea, near Karachi.

REMARKS ON THE GENUS *MONTICELLIUS* NOV. GEN.

Price (1934) has pointed out the differences which separate his two species *Learedius learedi* and *L. similis*, though he includes both of them under the same genus. In our opinion, these differences are so conspicuous that the creation of a new genus appears feasible for *L. similis* Price and the new form described above. The new genus *Monticellius* is distinguished from *Learedius* Price in the small size and slender shape of the body, much smaller length of the oesophagus and the intestinal bifurcation consequently occurring much in front of the acetabulum. The intestinal caeca in *Monticellius* are nearly straight and do not form the characteristic loops at their origin, nor do they curve in the region of the acetabulum as in *Learedius*. The testes in *Monticellius* are much smaller in number and do not form a large irregular mass as in *Learedius*; on the other hand, they appear to lie in a linear series, terminating much more in front of the hinder end of the body than in the latter genus. The external seminal vesicle is larger and the cirrus sac relatively much longer in the new genus. The position of the genital opening is also more anterior, and the ovary, though distinctly lobed, is not dendritic as in *Learedius*.

Monticellius indicum n. sp., which is designated as the type species of the new genus, resembles closely *Monticellius similis* (Price, 1934) but differs from it in the apparent absence of spines or verrucae, shape of the oral sucker, in the ratio of the size of the two suckers, in the smaller number of testes, and their arrangement in a linear series. The vitellaria extend a little more backwards in the new species, terminating a little behind the ovary and not at about its middle as in *similis*.

OBSERVATIONS ON THE SYNONYMY OF CERTAIN GENERA AND CLASSIFICATION OF THE FAMILY SPIRORCHIDAE.

Sinha described in June 1934 number of the *Records of the Indian Museum* a new blood fluke *Gomtiotrema sanguina*, which shows such a close similarity to
F. 2

the species of the genus *Plasmiorchis* described by me in May 1934, that the two genera must be held synonymous. The chief points of resemblance are the presence of an acetabulum, formation of the forwardly directed loops at the origin of the intestinal caeca one on each side of the oesophagus, and similarity in the topography of the genital organs, *i.e.*, the arrangement of the testes in a linear series in the median plane of the body in front of the ovary and position of the genital opening near the hinder end. The *vesicula seminalis*, *receptaculum seminis*, uterus, vitellaria, vitelline ducts and reservoir show also similarity in their position. As these two genera are identical and, therefore, synonymous, the name *Plasmiorchis* is accepted on the basis of priority.

Plasmiorchis sanguina (Sinha, 1934) resembles *Plasmiorchis pellucidus* Mehra, 1934, in the size of the body and oral sucker, entire and ovoid shape of the testes, position of the ovary from the hinder end, and nearly equal length of the oesophagus, but it differs in the retention of the acetabulum in the adult, in the number of the testes (8-9 in *pellucidus* and 12 in *sanguina*), and shape of the ovary which is divided into four or five lobes and has equal long and broad diameters in *Pellucidus*, but is dome-shaped and trilobed posteriorly in *sanguina*. The ovum in *pellucidus* is larger than in the latter species, in which the presence of the rudimentary cirrus sac has not been reported. *Pl. orientalis* Mehra resembles *Plasmiorchis sanguina* in retaining the acetabulum in the adult condition, and, moreover, its acetabulum is much larger than—almost double the size of—that in *sanguina*, though the body is shorter. The testes also differ much in number, size, and shape, in the two species.

Plasmiorchis hardellii Mehra, 1934, differs remarkably from the other four species of the genus, *i.e.*, *orientalis*, *pellucidus*, *obscurum*, and *sanguina*, on account of the large size and shape of the body, large size of the two suckers, specially the acetabulum which is almost double the size of the oral sucker in the greater length of the anteriorly directed loops at the origin of the caeca, in the presence of well-defined and fairly large genital loops of the caeca in the region of the genital opening, the characteristic narrow and irregular shape of the testes, 19-21 in number and very small in size relatively to the size of the distome, small size of the ovary, in the very small, practically obsolete condition of the external seminal vesicle, and in the presence of the well-developed cirrus sac with fairly thick muscular walls. Above all, the glandular vesicle in *hardellii* is enormously developed and much convoluted forming a conspicuous structure at the hinder end. It appears that some of the differences, such as the presence of well-developed cirrus sac, great reduction in size or practical disappearance of the external seminal vesicle and the enormous development of the glandular vesicle in *Plasmiorchis hardellii* justify its separation under a new genus for which we propose the name *Hemiorchis* n. g.

The synonymy of the genera *Tremarhynchus* Thapar, 1933, and *Coeuritrema* Mehra, 1933, was discussed before by us (1934) and the latter name was accepted on the basis of priority. The affinities of *Coeuritrema* with *Hapalorhynchus* Stunkard were discussed in 1933. Price (1934), however, places *Coeuritrema indicus* (Thapar) under the genus *Hapalorhynchus* as *H. indicus* (Thapar) because, in his opinion, it does not differ sufficiently from *H. gracilis* Stunkard to warrant its separation as a distinct genus, the differences being specific rather than generic. We do not accept this view on the basis of the description of *Hapalorhynchus* given by Stunkard. The presence of a large muscular cirrus sac, protrusible cirrus, and well-developed metraterm, in *Coeuritrema*, and their absence in the latter genus point towards that direction. The *vesicula seminalis* in *Hapalorhynchus* is much larger and occupies a different position, and the prostate gland which is also large takes most of the space between the seminal vesicle and anterior testis, in contrast to that of *Coeuritrema*, which occupies a limited space within the cirrus sac. The ovum also differs remarkably, being tricornuate in *Hapalorhynchus* and oval with two polar filaments in *Coeuritrema*.

The relationships of the blood flukes and classification of the Spirorchidae have been discussed by Stunkard (1923) and Mehra (1933 and 1934). Price (1934) points out that the genera of the Spirorchidae fall into two more or less well-defined groups, one consisting of monostomatous forms and the other of distomatous forms, but he thinks it undesirable to regard the two groups as sub-families on the basis of Ejsmont's view that evidence of transition occurs in some of the genera. The family Spirorchidae has been divided by us (1934) into sub-families on the basis of deep-seated and well-marked characters, such as the position of the genital opening, the number of testes—two or many—and their position in relation to the ovary, and the strongly developed or poorly developed condition of the cirrus sac but not on account of the presence of one or two suckers. The view that the monotomes are of polyphyletic origin has been held by several investigators. Morishita (1924) included in the genus *Cyclocoelium*, which belongs to the family Cyclocoelidae and is the most typical monostome group, two species, *C. vagum* and *C. distomatum*, which possess a ventral sucker. The two genera, *Spirorchis* Mac Callum and *Plasmiorchis* Mehra, of the family Spirorchidae resemble so closely in the topography of their genital organs that they are included in the same sub-family Spirorchinae, though they consist of monostomatous and distomatous species respectively. It was pointed out by us previously (1933) while discussing the affinities of *Spirhapalum* Ejsmont and *Diarmastorchis* Ejsmont with *Spirorchis* that the presence or absence of a ventral sucker, by itself, should not be considered as a feature of more than specific or generic rank. There is no distinct natural limit between the monostomes and distomes.

The question of allocating the genera *Amphiorchis* Price, 1934, *Learedius* Price, 1934, *Neospiorchis* Price, 1934, and *Monticellius* n.g. to their respective sub-families needs consideration. The genus *Amphiorchis* belongs to the sub-family Hapalotremiinae Stunkard on account of the position of the genital opening at about the middle or a little behind the middle of the body length and the forward position of the ovary with its associated ducts and that of the cirrus sac. It is more closely related to the genera *Coeuritrema* and *Hapalorhynchus* on account of the testes being simple instead of being divided into pre-ovarial and post-ovarial groups of follicles as in *Hapalotrema*. But it differs in the ventral position of the genital opening which lies behind the anterior testis, whereas in *Coeuritrema* and *Hapalorhynchus* the genital opening is dorsal and situated in front of the anterior testis. The external seminal vesicle and cirrus sac lie behind the anterior testis in *Amphiorchis*, but reverse is the case in *Coeuritrema* (cirrus sac is absent in *Hapalorhynchus*). The genera *Learedius* and *Monticellius* belong to the sub-family Spirorchinae on account of the position of the ovary with its associated ducts, genital opening and the cirrus sac near the hinder end as in *Spiorchis*, *Plasmiorchis* and *Hemiorchis* n.g. But they differ remarkably from the latter genera, among other features, in the large size and shape of the cirrus sac. The testes in *Learedius* are, however, large in number and irregularly arranged in a mass, whereas in *Monticellius* they foreshadow the arrangement in a linear series so characteristic of *Spiorchis*, *Plasmiorchis* and *Hemiorchis* n. g. It appears that we can arrange the genera of the Spirorchinae, *Learedius*, *Monticellius*, *Hemiorchis*, *Plasmiorchis*, and *Spiorchis*, in a continuous evolutionary series showing the transition from the strongly developed cirrus sac met with in the first two of the series to its reduction in size and practical disappearance in the last two genera and also the transition from the haphazard and irregular arrangement of the large number of testes characteristic of *Learedius* to their diminution in number and linear arrangement characteristic of the last three genera of the series. The genus *Neospiorchis* should be included in the sub-family Unicaeciinae Mehra, 1934, on account of the presence of single long, more or less coiled testis, almost spiral shape of the ovary which is situated along with the posterior part of testis in hinder part of the body, and the position of the genital opening in posterior half of the body near hinder end. Price has already pointed out that *Neospiorchis schistosomatoides* appears to be closely related to *Unicaecum Ruszkowskii* Stunkard. The important difference between these two species is the form of the digestive tract. While the latter species possesses only one caecum, *Neospiorchis* has two caeca that remain separate for a short distance and unite near the level of anterior pole of testis to form a long common caecum—a form of the gut resembling that of the family Schistosomatidae. It appears that the gut of *Unicaecum* represents a condition in which the two caeca have become united throughout their course.

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OBSERVATIONS ON THE DEVELOPMENT OF ZOOSPORANGIUM AND LIBERATION OF ZOOSPORES IN *ACHLYA* *DUBIA* COKER

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SUMMARY

1. The process of the development of zoosporangium and the liberation and further history of zoospores of *Achlya dubia* Coker, (Saprolegniaceae) has been studied both in living and fixed conditions.

2. During the development of the sporangium in the living condition four principal stages have been observed, viz., (a) the stage of inflow of protoplasm ending with the formation of a basal septum, (b) the stage of preliminary division, (c) the homogeneous stage, and (d) the stage of final division and formation of zoospores.

3. The zoospores, after liberation, undergo a period of rest followed by a single swimming period. Finally, they come to rest and germinate by means of germ-tubes.

4. The optimum temperature for the formation of sporangia and spores lies between 27°C and 30°C. While oxygen is indispensable for the formation of sporangia and liberation of zoospores, it inhibits the process in higher concentrations. Light seems to have no effect on the formation of sporangia.

5. The nuclei in the sporangium initial are at first irregularly distributed, but later become regularly arranged as the cytoplasm becomes divided into polygonal masses. Each of these polygonal masses has a single nucleus and represents a spore initial which finally rounds off to form the zoospore.

6. The internal structure of resting and motile zoospores has been described. The motile zoospore, as it comes to rest, gives rise to a germ-tube. The nuclear divisions at this stage seem to be amitotic.

The zoosporangium of Saprolegniaceae has been an object of critical study towards the close of the last century. Among the chief workers, Busgen (1) and, a little later, Ward (11) were the first to publish nearly concurrent results of their study. These workers held that the lines of preliminary division in the sporangium were cell-plates or nuclear-plates, and that they formed the ultimate source of a substance—the expulsive substance that lines the sporangium in the last stage and causes the expulsion of zoospores. De Bary (5) accepted the views put forward by these workers. Rothert (9) and Hartog (6), however, carried on a more critical study and denied the presence of anything like cell-plates or nuclear-plates

and the expulsive substance. The soundness of this conclusion has been proved by later investigators. Trow (8), working with a species of *Saprolegnia*, confirmed Hartog's observations and also brought forward some details of nuclear behaviour during spore formation. Among later workers, Weston (12) studied the process of spore formation and discharge in *Thraustotheca clavata*, and Couch (4) studied the same in *Leptolegnia*, *Achlya* and *Aphanomyces*. Cotner (3) contributed to the cytology and optimum conditions for the formation of zoospores in Oomycetes, including four Saprolegniaceous species, and Mathews (7) has given an account of the cytology of zoospores in *Leptolegnia*. In the present work an attempt has been made to make, as far as possible, a detailed study of the process of the development of sporangium and liberation of zoospores in *Achlya dubia* Coker, of the family Saprolegniaceae.

MATERIAL AND METHODS

The fungus was isolated from a local sample of water (8). The formation of sporangia was effected in a number of ways. The main underlying principle in each case was the sudden diminution of food supply in accordance with the general law established by Klebs. Pea-broth, lentil decoction, and bacto-peptone (1%), were some of the suitable rich liquid media employed to obtain vigorous growth of the fungus. Mycelium grown in any of these media, preferably in the first two, for about 48 hours and transferred to sterile, well-aerated, distilled water after being carefully washed for 30—40 minutes with the same, produced sporangia in 5 to 6 hours. A quicker and more convenient way for the formation of sporangia was to transfer the aerial mycelium of the fungus, growing on oat-meal agar for 8 to 10 days, direct to water, care being taken that no medium accompanies it. In this case the gemmae already formed in the aerial mycelium send out germ-tubes which form sporangia at their distal ends in 3 to 4 hours. The main advantage of this method is that one is relieved from the arduous task of carefully pre-washing the mycelium before finally transferring it to water. For studying the behaviour of zoospores after their liberation from the sporangium, well-aerated sterile conductivity water was used instead of distilled water. The development of sporangium in the living condition was observed through a water immersion lens while the behaviour of zoospores after liberation was studied in hanging drop cultures. For the fixation of sporangia Bouin's fluid (2), Flemming's weak solution and formalin-acetic-alcohol (2)—diluted four times—were used. But for a little shrinkage with Bouin's fluid, all the three gave quite satisfactory results. Preparations were stained both with crystal violet (following a modification of Gram's method) and iron-alum haematoxylin. For the fixation of zoospores, Cotner's method (3) of killing by exposure to 1% osmic acid vapours for 15—20 seconds and staining with crystal violet was closely followed.

OBSERVATIONS ON LIVING MATERIAL

With the sudden diminution of food supply, the growth of the hyphal tip practically ceases, and is followed by the gradual inflow of protoplasm into the tip. This is the beginning of sporangium formation. This inflow of protoplasm continues for a varying length of time and, when sufficient quantity has flown in, the formation of a basal septum takes place (fig. 2). The first indication of the formation of this septum is the appearance of a narrow, more or less transverse strip of hyaline area at the base of the dense granular contents (fig. 3). This hyaline area quickly increases in size and, in about less than a minute, assumes the form of a broad hyaline zone. Immediately following this, there appears a transverse septum at the lower surface of this hyaline zone (figs. 4, 5). Later, the hyaline zone gradually disappears while the septum becomes more prominent. The succeeding changes in the sporangium are concerned with the organization of zoospores from the dense protoplasm.

There is, at first, an appearance of a central axial vacuole as a result of the tendency of the protoplasm to occupy a peripheral position. The breadth of this axial vacuole depends on the amount of protoplasmic contents present in the sporangium. In sporangia with abundant protoplasm this presents itself in the form of a narrow irregular zone in the axial portion, while in those with deficient protoplasm it occupies a prominent central position reducing the protoplasm to a comparatively narrow peripheral layer. In all cases the presence of the vacuole was demonstrated admirably well by treating the sporangium at this stage with a neutral red solution. Following the appearance of the axial vacuole, cleavages make their appearance extending from the central region into the protoplasm (fig. 6). These cleavages seem to be the finer continuations of the axial vacuole because they take up colour with neutral red solution. Later, these cleavages become more and more prominent and form a system of intersecting lacunae which divide up the entire sporangium contents into roughly polygonal masses excepting a very thin peripheral protoplasmic layer which remains uncleft (fig. 7). This has been termed the stage of *preliminary division*. With the completion of this preliminary division, there follows immediately a stage in which the entire protoplasmic contents, hitherto organized into definite polygonal masses, become once again homogeneous with little or no indication of any previous division. This has been termed the *homogeneous stage* (fig. 8). It lasts for 2—4 minutes and is characterized by a slight contraction of the sporangium. In the present observation this contraction was, on an average, 1/10th of the width of the sporangium. This homogeneous condition has been shown by Rothert to be due to the rupture of the remaining peripheral layer of protoplasm lining the sporangial wall by the extensions of the internal clefts. In the present instance also the same explanation seems to be satisfactory. The rupture of this peripheral protoplasmic layer, which so long maintained the turgidity of the sporangium by acting as an osmotic layer, leads to the escape of vacuolar sap, with consequent

shrinkage in the sporangial width and obliteration of the lacunae of demarcation between the spore initials, resulting in a homogeneous state of the protoplasm.

In the final phase which next ensues, there is a rapid reorganization of the homogeneous protoplasm into polygonal masses or—as they may be now called—spore initials. This may be explained as due to the tendency of the protoplasm to aggregate round numerous centres: the nuclei, which are not visible in the living condition. These spore initials become delimited by delicate membranes; they swell up by imbibing water and become more and more separate from one another as well as from the periphery (fig. 9). That the water is imbibed by these spore initials was shown by the fact that when the sporangium at this stage was treated with a neutral red solution, the coloured solution appeared to diffuse into the spore initials from the periphery towards the centre. It is, therefore, presumed that a similar phenomenon takes place when the sporangium is kept under observation in water. This imbibing of water causes swelling of the zoospores—as they may be called now—with consequent swelling of the sporangium. Finally, the pressure from within breaks the sporangial wall at the apex and the zoospores rush out.

Liberation of zoospores.—As soon as the opening appears at the apex of the zoosporangium, the zoospores rapidly force their way out through the opening, often becoming constricted as they do so. One by one the zoospores emerge and become grouped in a hollow sphere (fig. 10). The outrush of the spores, so rapid at first, is seen to slacken after some time, but, in every case, as the zoospore comes near the opening, it quickens its speed and leaves it with a run as if there were some external attraction. In badly aerated cultures such as samples of water in which the mycelium had formed sporangia for 24–48 hours and the oxygen of which was practically used up by the fungus, it was found that zoospores were not discharged outside through an apical opening. The whole sporangium develops a *Dictyuchus state*, i.e., the spores either germinate within the sporangium (fig. 11) or come out through openings in the sporangial wall (fig. 12). This indicates that aeration of water plays an important rôle in the normal liberation of zoospores. Hartog (6) explains the escape of zoospores either as due to the attraction of zoospores by the aerated water outside or as due to a tendency to escape from the products of their own metabolism (i. e., from staling substances).

Behaviour of zoospores.—The zoospores are spherical, have finely granular contents and bear no cilia at this stage (fig. 13). After $1\frac{1}{2}$ to $1\frac{3}{4}$ hours, the entire protoplasmic content comes out in the form of a round amorphous mass through an opening in the wall of the zoospore (fig. 14, 15). In about 5 minutes this round amorphous mass assumes the characteristic structure of the motile zoospore. From a groove on the surface are seen coming out two delicate cilia that lash slowly back and forth until the zoospore finally frees itself with a jerk and swims actively away. The more tapering end is directed forward, and by the tractile action of

the anterior cilium the zoospore is drawn rapidly along, while the posterior cilium is drawn behind as a more or less passive rudder (fig. 16). It continues to swim for 80—90 minutes, the movements getting more and more sluggish towards the end, and finally comes to rest. If there are traces of any nutriment in the water, then the period of motility is cut short and the zoospore comes to rest earlier. As it comes to rest, it contracts itself to a sphere, the cilia disappear, and it becomes surrounded by a definite wall (fig. 17). After 30—35 minutes it puts out a germ-tube (fig. 18.) A careful attempt was made to find out if there was a second swimming stage of the zoospore; but, in all cases, it germinated after the first and the only swimming period.

TEMPERATURE

In an attempt to find the optimum temperature for the development of sporangium and liberation of zoospores, aerial mycelium from oat-meal agar was transferred to hanging drop cultures and kept at 10°, 20°, 24°, 27°, 28°, 30°, and 33°C. The following periods were required, at each temperature, for the liberation of zoospores.

Temp.	10°C	20°C	24°C	27°C	28°C	30°C	33°C
Time in hours	24—30	8—10	4—4½	3—3½	3—3½	3—3½	4½—5

At 33°C only a few sporangia were formed. From these it was evident that the optimum lay somewhere between 27°C and 30°C.

OXYGEN

Several samples of water with different oxygen concentrations were prepared with the view of observing the effect of oxygen on sporangium formation. Purified oxygen was passed in five flasks, each containing 100 cc. of sterile distilled water for 2, 5, 10, 15, and 20 minutes. Aerial mycelium from oat-meal agar was transferred in each of them in hanging drops and kept at 27°C. It was found that the sporangia were formed and the zoospores liberated in 3—3½ hours in the sample of water that oxygen was passed in for 2 minutes while the same was accomplished in about 4½ hours in the sample of water with the next higher concentration of oxygen. In samples of water in which oxygen was passed for 10, 15 and 20 minutes no sporangia were formed. These experiments show that while oxygen, in small concentrations, is indispensable for the sporangial formation, it inhibits the process in higher concentrations.

LIGHT

Light did not prove to have any influence on the formation of sporangia. Sporangia were formed and zoospores liberated in approximately the same time in day-light, red and violet light, and in complete darkness.

OBSERVATIONS ON FIXED MATERIAL

Sporangium.—A number of stages in the development of sporangium up to the liberation of zoospores have been observed in the fixed preparations. In the earliest stage the hyphal tip which is the sporangium initial, is, as shown in fig. 19, multinucleate and the nuclei are scattered irregularly in the uniformly distributed and finely granular cytoplasm. The nuclei are mostly round and their structure is similar to that of the nuclei in the vegetative hyphae (8). The next stage, represented in fig. 20, shows the differentiation of an axial vacuole, while the cytoplasm along with the nuclei is seen to have taken up a peripheral position. The axial vacuole is extending, at a number of places, into the cytoplasm. At a later stage (fig. 21) the entire cytoplasm is divided up into polygonal masses, each with a centrally placed nucleus. In the final stage shown in fig. 22, the sporangium is seen filled up with a number of rounded uninucleate spores, ready to be discharged. Cotner (3) describes the nucleus in the spore initials of *Achlya conspicua* as a crescent-shaped spindle with the bulk of the chromatin material at a position mid-way between the poles. Such a structure of nuclei in the spore initials has not been observed in any of the preparations.

Zoospores.—As shown in fig. 23, the resting zoospore is spherical in shape, and has finely granular and delicately reticulate cytoplasm and a cell-wall. Near its centre is the nucleus with a prominent nucleolus. The succeeding motile stage of the zoospore has been illustrated in fig. 24. There is no definite wall surrounding this motile zoospore; hence the more or less irregular outline. The cytoplasm, therefore, appears to be divided into a denser portion immediately surrounding the nucleus, and a peripheral vacuolated portion. The nucleus is much nearer to the surface and is extended into two soft, beak-like projections, each terminating in a deeply staining granule: the basal granule. The two delicate cilia have their insertions a little below the plasma membrane in these granules. The structure of the zoospore, when it has come to rest after the swimming period, is similar to that before the swimming stage. Here, the nucleus becomes round and is surrounded by a definite wall. The nucleus again shifts to the centre and there are no indications of the beak-like projections or cilia. A germinating zoospore has been represented in fig. 25. The nucleus of the zoospore is seen in a state of division that is probably of an amitotic type. The nuclei in the germ-tube are nearly spindle-shaped with the nucleolus in the middle.

In the end, the writer expresses his gratitude to Prof. J. H. Mitter for providing him laboratory facilities, and gratefully acknowledges his indebtedness to Dr. R. K. Saksena, under whose supervision this work has been carried out, for his helpful suggestions and criticisms.

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EXPLANATION OF PLATES

I

Figs. 1 to 10. Various stages in the development of a sporangium. 1 and 2. Sporangium initial becoming filled up with protoplasm. 3, 4 and 5. Stages in the formation of basal septum. 6. Beginnings of cleavages. 7. Completion of preliminary division. 8. Homogeneous stage. 9. Spores completely formed and ready to be discharged out. 10. Zoospores discharged out in a hollow sphere ($\times 500$).

II

Figs. 11 and 12. Mature sporangia in badly aerated water.

11. Spores sprouting while in the sporangium ($\times 500$).

12. *Dictyuchus* state of sporangium ($\times 500$).

Fig. 13. A resting zoospore ($\times 1000$).

Fig. 14. The contents of a zoospore in the process of coming out ($\times 500$).

Fig. 15. Entire contents of the same zoospore discharged out in the form of a round amorphous mass ($\times 1000$).

Fig. 16. A motile zoospore ($\times 1000$).

Fig. 17. A resting zoospore after the completion of the swimming period ($\times 1000$).

Fig. 18. A germinating zoospore ($\times 1000$).

Figs. 19 to 21. Four different stages in the development of sporangium as observed in fixed preparations. 19. Young sporangium initial with irregularly distributed nuclei. 20. A later stage with an axial vacuole. 21. Sporangium with the cytoplasm divided up into roughly polygonal and uninucleate portions. 22. Sporangium with a number of rounded uninucleate zoospores. ($\times 500$).

Figs. 23 to 25. Different stages of zoospore in fixed condition. 23. A resting zoospore ($\times 24$), a motile zoospore ($\times 25$), a germinating zoospore ($\times 1000$).

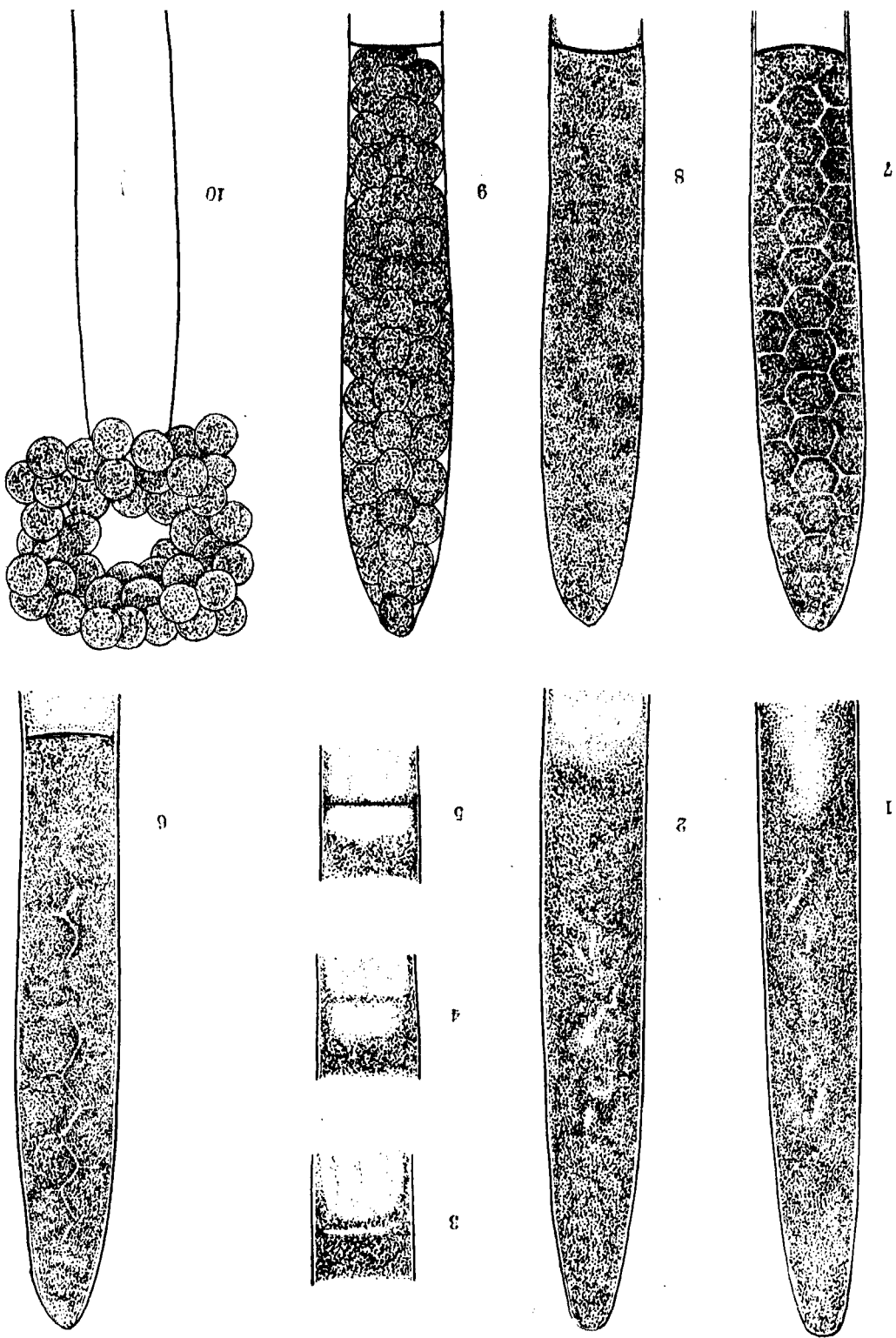
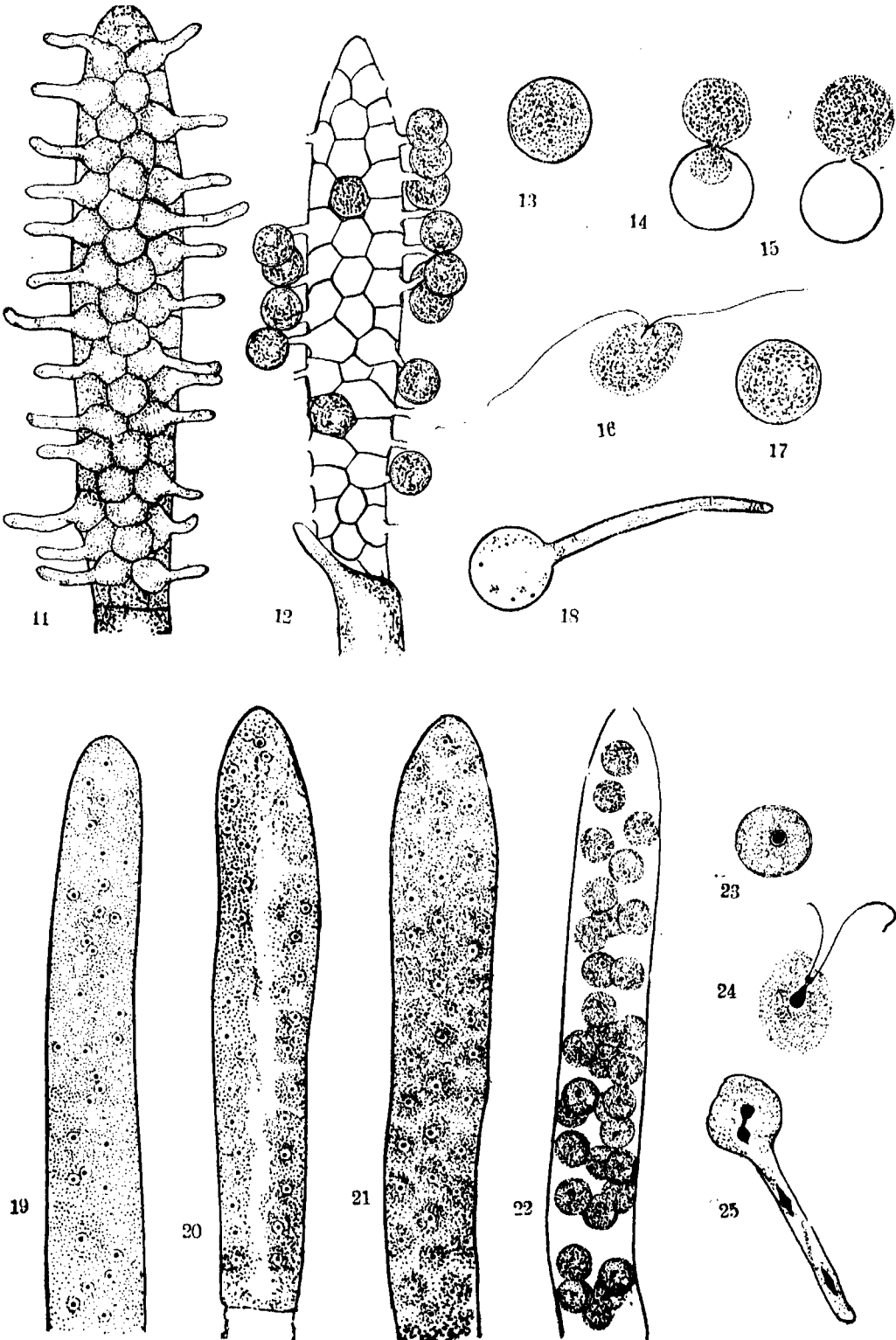


PLATE II

M. S. MURDIA—*Observations on the Development of Zoosporangium, etc.*



CHEMICAL EXAMINATION OF THE ESSENTIAL OIL FROM THE PEELS OF NAGPUR ORANGES

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(Received on August 4, 1939)

SUMMARY

1. The essential oil from peels of Nagpur oranges has been isolated for the first time by steam distillation.
2. Further examination of the essential oil revealed the fact that the essential oil consists of over 91 per cent. of d-limonene together with smaller quantities of terpenene, carene, linalool and methyl anthranilate
3. The essential oil is contained in the peels to the extent of 1 per cent. of the fresh material.
4. The commercial manufacture of orange oil from Nagpur oranges would be a very profitable proposition, provided industries for the canning of oranges and making them into preserves are also simultaneously developed.

Although orange oil is a common commercial commodity and has been examined by a large number of workers in Europe and America, yet up to this time no attempts appear to have been made to examine the essential oil derived from the peels of oranges of Indian or even of Asiatic origin. It is a well-known fact that the quality and chemical characteristics of essential oil vary considerably according to locality, climatic and soil conditions under which the essential oil plant is grown. This will be apparent from the table below :—

TABLE I

Constants of orange oils from different sources.

Source of orange oil.	Sp. Gr.	Optical rotation.	Residue.
Jamaica	0.8481—0.8488	+ 97.47—98.2°	1.4%
Italy	0.8480—0.8530	+ 95—98°	2—4%
Sicily	0.8480—0.8500	+ 98—99°	1.5—2%
West Indies	0.8475—0.8550	+ 98.3°	...
Dominica	0.8550	+ 96.58°	...
Florida	0.8560	+ 96.25°	...

There are five different varieties of sweet orange usually met with in the Indian market, and they are: (1) the Sylhet or Khasia orange grown in Assam, (2) the Nagpur orange grown in the Central Provinces, (3) the Delhi orange grown in the Punjab and the western districts of the United Provinces, (4) the Poona orange grown in Poona and on the neighbouring Deccan plateau, and (5) the South Indian orange grown in Coorg, Mysore and the Nilgiri hills. According to Sir George Watt (3), the Sylhet and the Nagpur oranges are pure varieties, different from those known anywhere else in the world, whereas the remaining three types are hybrids of the Mozambique, Manderin, and Maltese, oranges.

As the Nagpur orange constitutes a distinct variety, the essential oil from which has never been examined before, it was thought desirable to submit it to a systematic chemical examination. It is interesting to note in this connection that as yet no attempts have been made to manufacture essential oil from Nagpur oranges in spite of the fact that the peels contain a large proportion of essential oil which is very important from the medicinal as well as commercial points of view. Incidentally, it might also be mentioned that the Nagpur oranges have a comparatively long season—from November to May—and they are then available in such large quantities that prices go down tremendously. The peels of Nagpur oranges which are fairly thick and form a good proportion of the entire fruit, are always thrown away and no use is made of them. In season time they become so abundant and consequently so cheap that very often it becomes apparent that, on account of the perishable nature of the fruit, it is not very profitable to cultivate oranges. But if an attempt is made to can the fruit or make preserves out of it and utilize the peels for the manufacture of essential oil, then the cultivation of oranges can really become a profitable undertaking for the agriculturists and also a great source of national wealth.

As already stated, orange oil is very important both from the commercial and medicinal points of view and, as such, commands a high price in the market (Rs. 17/- per lb., Italian). It is extensively used in perfumery and as a flavouring material for syrups, jams, jellies, aerated drinks, sugar candies, Indian sweets, toffees, lozenges, etc. Medicinally, according to Dymoch (1), the essential oil is considered hot and dry and is used as a stimulating liniment. It is also regarded as refrigerent and astringent and is said to be digestive and to check bilious vomittings and intestinal worms.

d-Limonene has been found in European orange oil, sometimes to the extent of 90 per cent., by Wallach (2).

EXPERIMENTAL

Fifty kilos of fresh peels of the genuine specimens of Nagpur oranges obtained from the local market were distilled with water in several instalments from a 20-gallon copper still (tinned inside), the selection of the fruit being restricted to the fully ripened

and well-grown large variety. Even slightly under-ripe and over-ripe fruits were rejected. The distillate, measuring about 350 litres, was collected and the oil that separated at the top was skimmed off. The weight of the skimmed oil was 96 grams. The oil remaining in suspension in the aqueous distillate was extracted with petroleum ether and, on removal of the solvent, 404 grams of the substance were obtained. The skimmed oil as well as the extracted oil, after filtration and dehydration with anhydrous sodium sulphate, was submitted to fractional distillation under a vacuum of 68 mm. The following fractions were collected :

TABLE II

Fractionation of orange oil.

Quantity of oil take = 212 gms.

Fraction No.	Boiling range (68 mm.)	Weight of the distillate.	Yield %.
1.	Below 80°C	10.5 Gm.	5
2.	80—100°C	11.9 „	5.7
3.	100—114°C (const. at 114°C)	170 „	80.9
4.	114—140°C	13.7 „	6.5
5.	Residue	3.9	1.9

The physical and chemical constants of the above mentioned fractions were determined and they are given in the following table :

TABLE III.

Constants of the above fractions.

Fraction No.	Sp. Gr. (15°C)	Ref. Index (15°C)	Optical rotation (36°C).	Sap. value.	Acid value.	Ester value.
1.	0.8150	1.476	+ 103.31	21.8	nil	21.8
2.	0.8209	1.474	+ 49.08	69.5	„	69.5
3.	0.8476	1.475	+ 78.45	nil	„	nil
4.	0.8690	1.480	+ 102.6	44.7	6.22	38.5

The physical and chemical constants of the skimmed oil were also determined after it was filtered and dried, and they are as follows :

Skimmed oil	0.8501	1.468	+ 85.03	89.4	0.84	88.6
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In order to free the different fractions from very small quantities of esters accompanying them, all the fractions were treated with alcoholic potash and refluxed for about two hours. The alcohol was then distilled off and the residual terpenes recovered by steam distillation. The table on p. 178 gives the physical constants of the unsaponifiable matters obtained from the different fractions:

TABLE IV
Constants of unsaponifiable matters.

Fraction No.	Sp. Gr. (15°C)	Ref. Index (15°C)	Optical Rotation (36°C)
1a.	0.8666	1.4777	+73.17
2a.	0.8642	1.463	+86.63
3a.	0.8319	1.462	+63.45
4a.	0.7975	1.457	+39.16
Original oil	0.8642	1.456	+121.59

Examination of the residue.—The residue mentioned above was extracted with alcohol, and from the alcoholic solution a very small quantity of a white amorphous substance was recovered. On examination it was found to melt sharp at 60°C and was identified to be a wax. On ignition, it burnt with a luminous but non-smoky flame, emitting odour of burning candles. This was definitely not a stearoptene nor the white amorphous substance described by Moore in Californian Orange Oil.

Examination of fraction No. 3.—This was refractionated under ordinary pressure and the following fractions were collected:

TABLE V
Refractionation of main fraction

Fraction No.	Boiling range.	Weight of the distillate.	
6.	140–170°C	7.1	Gm.
7.	170–173°C	16.8	"
8.	173–176°C	143.7	"
9.	176–180°C	2.4	"
9a	Residue	0.1	"

The various remaining fractions were refractionated at the ordinary pressure; the following tables give the results obtained:

TABLE VI
Refractionation of fraction No. 6.

Fraction No.	Boiling range (°C).	Weight of fraction (Gm.)	Sp. Gr. (15°C).	Ref. Index. (15°C).	Optical rotation.	Main constituent.
10.	165–172	3.5	0.8399	1.432	+100	Terpenene.
11.	172–174	2	0.8364	1.475	+105	D-Limonene.
12.	175	1.2	0.8447	1.476	+125	Ditto.
13.	Residue.					

TABLE VII

Refractionation of fraction No. 7.

Fraction No.	Boiling range.	Weight of fraction.	Sp. Gr.	Ref. index.	Optical rotation.	Main constituent.
14.	163—166	2.4	0.8469	1.470	+100	...
15.	169—173	4.5	0.8420	1.473	+112.5	Carene
16.	173—174	9	0.8494	1.475	+100	D-Limonene
17.	175—176	0.79	0.8171	1.466	...	...
18.	Residue	0.2	...	1.479	...	...

Fraction No. 8 from Table V was further fractionated (Fraction No. 19) and it was found to boil almost completely within the range 175—176°C and was identified to be pure d-limonene (Sp. Gr. 0.8505, Ref. index 1.4755 at 15°C and optical rotation +100° at 39°C). The tetrabromide prepared by the ordinary method melted at 104—105°C.

TABLE VIII

Refractionation of fraction No. 9.

Fraction No.	Boiling range.	Weight of fraction.	Sp. Gr.	Ref. Index.	Optical rotation.	Main constituent.
20.	Below 170°C.	1.78	0.8390	1.476	+100°	D-Limonene
21.	175°C	1.2	0.8520	1.476	+100°	Ditto.
22.	Residue	0.05	...	1.481		

TABLE IX

Refractionation of fraction No. 4 (55 mm.)

Fraction No.	Boiling range.	Weight of fraction.	Sp. Gr.	Ref. Index.	Optical rotation.	Main constituent.
23.	85—100°C	3.2	0.8594	1.4755	+100°	D-Limonene
24.	Above 100°C.	0.6	0.9010	1.4805	+5.2	Methyl anthranilate.

Fraction No. 2a was suspected to be d-linalool, but it could not be confirmed for want of sufficient material. In the case of the other fractions the confirmation was arrived at by exclusive colour reactions and also by the preparation of derivatives wherever feasible.

One of the authors (B. K. M.) wishes to express his indebtedness to the Kanta Prasad Research Trust of the Allahabad University for a scholarship that enabled him to take part in this investigation.

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CHEMICAL EXAMINATION OF THE FIXED OIL FROM THE SEEDS OF *EUPHORBIA DRACUNCULOIDES* LAM.

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(Received on August 4, 1939)

SUMMARY

The fixed oil from the seeds of *Euphorbia dracunculoides* Lam. was found to have the following composition on analysis:

Total fatty acids	...	...	...	92.4 %
Myristic acid	..	...	...	0.294 %
Palmitic acid	.	...	...	7.081 "
Stearic acid	...	...	...	15.34 "
Arachidic acid	...	...	...	5.265 "
Behenic acid	...	...	...	0.595 "
Linolenic acid	...	...	...	8.59 "
Linolic acid	...	...	...	23.488 "
Oleic acid	...	...	...	30.500 "
Unsaponifiable matter	...	...	...	1.850 "

Euphorbia dracunculoides Lam., known as "Titli" in Hindi, is a glabrous, much-branched annual herb, chiefly found in Northern India (Moradabad, Sub-Himalayan tracts in Rohilkhand, North Oudh and Bundelkhand). It is cultivated in the plains of the Punjab and Bengal, and southwards to Kanara and Coromondal, in Arabia and in tropical Africa. The most important part of the plant are the seeds which are in capsules and about one-eighth of an inch in length. They are of great medicinal value and appreciated as such in Indian villages. The oil expressed from the seeds is used as a liniment in cases of gout or rheumatism, and as an application to the eyes in case of ophthalmia. In small doses it is also used internally for various kinds of digestive disorders.

In view of the fact that in spite of its medicinal importance, the fixed oil has not been yet chemically examined, the present authors thought it advisable to submit it to a systematic chemical examination.

The oil is present in the seeds to the extent of 15.5 per cent. On complete analysis, it was found to be consisting of the glycerides of myristic, palmitic, stearic, arachidic, behenic, linolenic, linolic, and oleic, acids. The unsaponifiable matter in the oil (to the extent of 1.85 per cent.) was found to be ordinary sitosterol. Apparently, the medicinal properties of the oil are due to the comparatively large proportion of the latter substance.

EXPERIMENTAL

Two kilos of the dry and crushed seeds were exhaustively extracted with benzene, and 331 grams of clear brownish-yellow oil were obtained (yield=15.5%). It was given a preliminary purification with animal charcoal and Fuller's earth, after which its general chemical and physical properties were determined (see Table I). The oil is free from nitrogen or sulphur, and belongs to the class of semi-drying oils :

TABLE I

General chemical and physical properties of the oil.

Solidifying point	= 16.2°C
Gp. Gr. (26°C)	= 0.9218
Refractive index (30°C)	= 1.4583
Saponification value	= 187.5
Iodine value (Wiji)	= 119.5
Acetyl value	= 33.4
Acid value	= 8.9
Hehner value	= 92.4
Reichert-Missel value	= 0.54
Unsaponifiable matter	= 1.85 %

Two hundred and ten grams of the oil were saponified as usual with alcoholic caustic potash, and the soap formed after complete removal of the alcohol and drying was extracted with ether in order to remove the unsaponifiable matter. The residue was then dissolved in sufficient amount of warm water and decomposed with dilute sulphuric acid in presence of petroleum ether (B. P. 40–60°C). The petroleum ether solution of free fatty acids thus obtained was washed free from traces of sulphuric acid by distilled water, dried and the solvent removed by distillation, when the mixed fatty acids were obtained as a viscous semi-solid mass. Table II gives the constants of the mixed fatty acids :

TABLE II

Constants of the mixed fatty acids.

Sp. Gr.	= 0.9487
Neutralisation value	= 189.8
Mean molecular weight	= 285.4
Iodine value	= 125.8
Refractive index (30°C)	= 1.4563

The mixed fatty acids were then separated into saturated (solid) and unsaturated (liquid) fatty acids by Twitchell's lead-salt-alcohol method (1, 3), and Table III gives the percentages, iodine values, and mean molecular weights, of the saturated and unsaturated fatty acids:

TABLE III

Acid.	Percentage in mixed acids.	Percentage in oil.	Iodine value.	Mean M.W.
Saturated	32.2	29.75	3.1	290.8
Unsaturated	67.8	62.65	139.5	280.64

Examination of the unsaturated acids.—The unsaturated acids separated by the above method were further examined and their constituents determined by the method of Jameison and Boughmann (2), by preparing their bromine addition products. About 5 grams of the liquid acids were dissolved in 100 cc. of dry ether and dry bromine gradually added at 0°C until the colour persisted. After further cooling at 0°C for five hours, the precipitate was removed to a tared filter paper, washed with chilled dry ether, dried, and weighed. The melting point of the substance was 178°–179°C corresponding to that of linolenic-hexabromide (181°C).

The ether soluble portion was dissolved in petroleum ether (B. P. 40°–60°C) and cooled in a refrigerator, when cubical crystals of linolic-tetrabromide (M. P. 113°C) separated out from the solution, showing thereby the presence of linolic acid. The filtrate was evaporated to dryness and the bromine content estimated. Table IV gives the results of analysis of the bromine addition products:

TABLE IV

Bromine addition products.

Weight of acid taken for bromination	...	...	5.013
Weight of linolenic-hexabromide	...	...	1.8777
Percentage of linolenic acid	...	...	13.73
Weight of linolic-tetrabromide	...	...	3.300
Weight of the residue	...	...	5.627
Bromine content of the residue	...	...	41.4%
Weight of the dibromo-oleic acid in residue	...	...	3.771
Weight of linolic-tetrabromide in the residue	...	...	1.856
Weight of total linolic-tetrabromide	...	...	5.156
Linolic acid equivalent to the tetrabromide	...	...	1.879 (37.5%).
Oleic acid equivalent to the dibromide	...	...	2.406 (48.7%).

The proportions of linolenic, linolic, and oleic acids were also determined from the iodine value of the liquid fatty acids, and the proportions calculated in this way were found to be almost identical with the proportions determined from the bromine addition products.

Examination of the saturated fatty acids.—The saturated fatty acids obtained by the lead-salt-alcohol method were freed from traces of liquid fatty acids by pressing on a porous plate. The acids thus obtained were almost colourless and melted between 56° and 60°C. For the purpose of separation, the mixed acids were converted into their methyl esters by dissolving in methyl alcohol and passing hydrogen chloride to saturation. The esterification was completed by refluxing on the water bath for about 18 hours. The methyl esters formed were neutralized with sodium bicarbonate, washed with distilled water, and extracted with ether. After drying and removal of the solvent, the mixed methyl esters were fractionated under reduced pressure. The iodine and the saponification values of each fraction were determined and the mean molecular weight calculated. Table V gives the results obtained :

TABLE V

Fractionation of the methyl esters of the saturated fatty acids.

Fraction No.	Boiling range (4.5 mm.)	Quantity (gm)	I. V.	Mean M. W.	Sap V.	Unsaturated acid (%)
1.	140°—145°	3.12	0.85	253.4	221.4	0.64
2.	147°—149°	4.53	1.12	267.5	209.7	0.84
3.	151°—153°	5.18	1.32	273.1	205.4	0.99
4.	155°—159°	2.94	1.45	277.8	201.9	1.09
5.	162°—165°	3.47	1.89	282.3	198.7	1.42
6.	168°—171°	3.87	2.14	285.5	197.1	1.61
7.	175°—180°	4.13	3.45	289.9	193.5	2.59
8.	183°—185°	2.57	4.51	294.6	190.4	3.38
9.	186°—192°	3.41	8.92	308.7	181.7	6.71
10.	192°—195°	2.18	8.95	314.6	178.3	6.74
11.	Residue above 195°	1.75	11.4	315.5	178.1	8.59

Total percentage of unsaturated fatty acids = 2.61.

TABLE VI

Proportion of fatty acid in esters

Fraction No.	M. W. of acids.	Myristic acid.		Palmitic acid.		Stearic acid.		Arachidic acid.		Behenic acid.	
		(Gm.)	(%)	(Gm.)	(%)	(Gm.)	(%)	(Gm.)	(%)	(Gm.)	(%)
1.	253.41	0.284	9.1	2.836	91.9	...	...	...	...	...	...
2.	267.8	...	..	2.655	59.6	1.875	41.4	..	...	...	...
3.	273.0	..	...	2.030	39.2	3.150	60.8	...	...	...	...
4.	277.8	..	...	0.642	22.2	2.298	77.8	...	...	...	...
5.	280.3	...	...	0.333	9.6	3.137	90.4	...	...	...	...
6.	285.57	...	...	...	...	2.644	94.4	0.216	5.6	..	...
7.	290.1	...	...	...	...	3.230	78.2	0.900	21.8	...	...
8.	295.1	...	...	...	..	1.552	60.4	1.018	39.6	...	...
9.	307.4	..	...	...	...	0.523	17.4	0.289	82.6	...	...
10.	313.7	...	...	...	...	...	...	2.047	93.9	0.139	6.1
11.	318.7	...	...	...	...	...	...	1.331	76.1	0.419	23.9

TABLE VII

Acid.	Percentage in saturated acids.	Percentage in unsaturated acids.	Percentage in total acids.	Percentage in crude oil.	Percentage in purified oil.
Myristic	0.99	...	...	0.294	0.318
Palmitic	23.8	...	...	7.081	7.666
Stearic	52.6	...	...	15.349	16.939
Arachidic	17.7	..	...	5.265	5.699
Behenic	2.00	...	...	0.595	0.644
Linolenic	...	13.73	9.30	8.59	8.680
Linolic	..	37.5	25.42	23.488	23.819
Oleic	...	48.70	33.01	30.50	30.855

Unsaponifiable matter.—The unsaponifiable matter extracted as described above was crystallized from alcohol in colourless plates melting at 135°C, and was found to be identical with ordinary sitosterol.

One of the authors (J. N. T.) wishes to express his indebtedness to the Kanta Prasad Research Trust of the Allahabad University for a scholarship that enabled him to participate in this investigation.

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ESSENTIAL OIL FROM THE SEEDS OF *ZANTHOXYLUM* *ALATUM* ROXB

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SUMMARY

The essential oil of *Zanthoxylum alatum* Roxb. has been obtained by steam distillation of the powdered fruits in an yield of 2.7 per cent. Further investigation of the oil through rectifications and fractionations resolved it mainly into dipentene (39.2%) and linalool (42.4%), together with smaller proportions of sabinene, citral, citronellal and geraniol. The presence of citronellal is also assumed in the fraction containing geraniol.

Zanthoxylum alatum Roxb. known in Sanskrit and Hindi as *Tejbal*, and in Bengali as *Nepali Dhamia*, is a shrub belonging to the Natural Order of Rutaceae. It is a common plant in the temperate regions of the Himalayas, e.g., the Kumaun hills, Nepal and Bhutan, the Darjeeling district, and also in the submontane regions of the Himalayas, e.g., the Terai and also Monghyr and Mozaffarpur districts. It also grows abundantly in Garo, Khasia and Manipur hills in Assam. The fruits are generally collected at the end of autumn, and the dried product is a commercial commodity in most of the bazars of Northern India, being extensively used in the indigenous systems of medicine as an aromatic and tonic in fever, dyspepsia and cholera. The fruits are also used as a remedy for tooth-ache and as a stomachic and carminative.

According to Kirtikar and Basu (5) the carpels of the fruits are reputed to yield an essential oil isomeric with turpentine and which is like eucalyptus oil in odour and properties. The oil is said to possess antiseptic, disinfectant and deodorant properties. But the oil does not appear to have been chemically investigated at any time in India. It is of interest to note in this connection that some European authors have published works under the heading of the essential oil of *Zanthoxylum alatum* which certainly could not have been derived from an authentic specimen of that material, and some of which, on later investigation, have been proved to be derived from an altogether different source. Thus, Messrs Schimmel & Co. (9) obtained from the carpels of certain specimens of seeds that they obtained in a London Market as those of *Zanthoxylum alatum*, 3.7 per cent. of an oil which had a lemon yellow colour and a peculiar smell reminding that of water fennel. Upon continued distillation an additional 0.9 per cent of a crystalline substance was obtained, which on further investigation by Semmler and Schlossberger (10), was

found to be the dimethyl ether of phloracetophenone. The main oil also, according to later workers, contains a hydrocarbon named Zanthoxylene and Cumic aldehyde. The specimen of *Zanthoxylum alatum* with which the present workers have carried out their investigation and which has been definitely identified as such in the Botany Department of the Allahabad University, contains none of the constituents mentioned above. It contained, on the other hand, constituents like linalool, dipentene, citral, and sabinene, which had never been detected before in any specimen of *Zanthoxylum* oil.

Work on other varieties of *Zanthoxylum* has been done before, and the essential oil from the carpels examined by a number of chemical investigators. Thus the essential oil from *Zanthoxylum Budrunga* Wall (12) has been investigated by Simonsen and Ran, and that from *Zanthoxylum ovalifolium* by Simonsen (11). The essential oil from the fruits of *Zanthoxylum piperitum* D. C., generally known as *Piper Japonica*, has been investigated by Messrs Schimmel & Co. (8) and also by Stenhouse (13). The essential oil of *Zanthoxylum Hamiltonium* Wall has been investigated by Helbing (3), that of *Zanthoxylum Ochroxyllum* D. C. by Leprince (6), of *Zanthoxylum Aubstia* D. C. and of *Zanthoxylum peckoltianum* Engl. by Gildmeister (2). The essential oil from *Zanthoxylum Rhapsa* D. C. was investigated by Sanjiva Rao, Sudborough and Watson (7) and was found to consist of 90 per cent. of sabinene.

The seeds of *Zanthoxylum alatum*, on steam distillation, yield about 2.7 per cent. of a clear pale yellow essential oil, with a pleasant and persistent aromatic odour characteristic of the drug with a distant resemblance to linaloe oil. On exhaustive fractionation under reduced and also ordinary pressure, the oil was resolved into a number of constituents, amongst which the following were definitely identified: dipentene, sabinene, linalool, citronellal and citral. In addition to these, the presence of geraniol and citronellol has been tentatively shown.

EXPERIMENTAL.

Preparation of the essential oil of Zanthoxylum alatum.—Nine Kilos of a good and authentic sample of the seeds of *Zanthoxylum alatum* was obtained from the local market, and the coarsely ground material in lots of 2 to 2.5 kilos at a time was distilled with water from a large distilling apparatus made of copper and fitted with a copper worm condenser. The distillation was continued till the distillate, which was opalescent in the beginning and contained droplets of oil, began to run perfectly clear. The distillate was shaken with light petroleum ether (B. P. 30–60°C) in a large separator and the upper petroleum ether layer after dehydration with anhydrous sodium sulphate was distilled from a water bath till the petroleum ether no longer came over. The

residual essential oil was kept in the vacuum desiccator for 24 hours in order to dry it completely and also to free it from traces of the solvent. The residual essential oil thus obtained is a clear light yellow oil with a pleasant and persistent aromatic odour characteristic of the drug and reminding one of linaloe oil. It has an astringent taste and a bitter after-taste. It gives no coloration with alcoholic ferric chloride and does not reduce Fehling's solution or ammonical silver-nitrate. Estimation of phenol in the oil showed the absence of such bodies in the substance. The following physical and chemical constants of the oil were determined :

TABLE I

Specific gravity at 23°C	=0.9327
Refractive index at 26°C	=1.467
Acid value	=6.57
Saponification value	=12.12
Ester value	=5.55
Ester value after acetylation	=166.8

Rectification of the essential oil.—150 c.c. of the essential oil was fractionally distilled under reduced pressure (5 mm.) using a distilling flask of 250 cc. capacity with a rectifying neck of four bulbs blown below the delivery tube. The following fractions were collected :

TABLE II

Fraction No.	Boiling range.	Value of the distillate.
1	30—35°	11 c. c.
2	35—50°	6 c. c.
3	50—75°	3 c. c.
4	75—85°	36 c. c.
5	85—90°	33 c. c.
6	90—95°	23 c. c.
7	95—105°	18 c. c.
8	105—130°	8 c. c.
9	Residue	6 c. c.
	Experimental loss	6 c. c.
Total		150 c. c.

Fraction 1.—This, on redistillation at the ordinary pressure, boiled completely between 85°—90°C, and was nothing but the tail fraction of petroleum ether. Chemically it was perfectly inert and, on keeping in a corked flask, almost

completely evaporated. From the boiling range of the fraction it is quite possible that it might contain some diacetyl, a substance which has been frequently found in essential oils, but this could not be definitely ascertained for want of sufficient material.

Fraction 2.—This was re-distilled at the ordinary pressure, when it was resolved into the following sub-fractions with the composition given below:

TABLE III

No.	Boiling range.	Quantity.	Composition (main).	Correct B. P.
1	165–170°C.	4 c. c.	Sabinene	163–165°
2	170–178°C.	2 c. c.	Dipentene- Sabinene mixture.	
3	178–181°	1 c. c.	Dipentene	179–180°

Fraction 3.—This was resolved into three fractions as given in the following table:

TABLE IV

No.	Boiling range.	Quantity.	Composition (main).	Correct B. P.
1	165–175°	1 c. c.	Sabinene-dipen- tene mixture	
2	178–181°	1.5 c. c.	Dipentene	179–180°
3	Residue	1.5 c. c.		

Fraction 4.—This was resolved into four fractions as given in the table below:

TABLE V

No.	Boiling range.	Quantity	Composition (main).	Correct B. P.
1	180–182°	20 c. c.	Dipentene	179–180°
2	182–186°	6 c. c.	Dipentene (mainly.)	179–180°
3	186–194°	4 c. c.	Unidentified	
4	Residue	5 c. c.		

Fractions 1 and 2 together, on redistillation, were resolved into pure dipentene boiling between 179–182°C and were definitely identified by preparation of the

tetrabromide by the action of bromine on the substance dissolved in glacial acetic acid to which a small quantity of water had been added.

Fraction 5 — This together with residues of fractions 3 and 4, on refractionation, was resolved into the constituents given below :

TABLE VI

No.	Boiling range.	Quantity.	Composition (main).	Correct B. P.
1	184—188°	7 c. c.	Mainly dipentene	179—181°
2	190—195°	8 c. c.	Dipentene-linalool mixture.	
3	195—199°	12 c. c.	Linalool	198°
4	Residue	4 c. c.		

The linalool was definitely identified by formation of the phenyurethane derivative, M. P. 63—64°.

Fractions 6 and 7.— These were combined together and, on refractionation, were resolved into the components given below :

TABLE VII

No.	Boiling range.	Quantity.	Composition (main).	Correct B. P.
1	195—199°	16 c. c.	Linalool	197—199°
2	200—204°	2 c. c.	Linalool-citronellal mixture	
3	204—208°	7 c. c.	Citronellal	205-206°
4	220—234°	9 c. c.		

The above No. (4) fraction was refractionated when the following were obtained :

TABLE VIII

No	Boiling range	Quantity.	Composition (main).	Correct B. P.
1	202—210°	Citronellal	4 c. c.	205-206°
2	216—240°	Mainly geraniol	3 c. c.	230°
3	Residue	...	2 c. c.	

The citronellal in the above fractions was identified by formation of the semicarbazone.

Fraction 8.—This, on redistillation at the ordinary pressure, boiled almost completely between 220° and 232°C, and was found to be a mixture of citral (B. P. 228°) and geraniol (B. P. 229-230°) together with perhaps small quantities of citronellal (B. P. 222°C). Citral (3·7%) was estimated in the original essential oil by

means of N/2 hydroxylamine hydrochloride and titrating the hydrochloric acid generated by N/2 alcoholic potassium hydroxide, using methyl-orange as indicator in accordance with the method described by the essential oil sub-committee. It was also definitely identified by formation of the semicarbazone.

As regards geraniol in the mixture no definite derivative could be prepared, but the characteristic smell of geraniol was quite marked which, on keeping exposed for some time, changed note from rose to lemon, thereby showing that it was converted into citral by oxidation. As citronellal has an odour almost identical with that of geraniol and it is also almost always associated with geraniol in natural perfumes, it is quite reasonable to assume the presence of citronellal in the above mixture containing geraniol.

The residue.—This was a brown viscous mass which deposited a small quantity of fine needles on standing for some time, but the quantity was too small for chemical examination. The residual syrup was found to be free from the esters of benzoic or cinnamic acids frequently found in essential oils, since on hydrolysis with potassium hydroxide, acidification and steam distillation, no benzoic or cinnamic acids came over in the distillate. The viscous mass had an acid value of, 146.5 and gave a liquid bromoderivative containing 27.5 per cent of bromine. From its general properties it appeared to be a mixture of resins, lauric and oleic acids, so often found in unrectified essential oils, and it is due to the presence of these acids in partly free and partly esterified state, that the crude essential oil of *zanthoxylum alatum* has acid and ester values. The substance was found to be free from linolic or linolenic acids by following the well-known bromine addition method of Jamieson and Baughmann (4).

One of the authors (J. N. T.) wishes to express his grateful thanks to the Kanta Prasad Research Trust of the Allahabad University for a Scholarship that enabled him to take part in the investigation.

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INFLUENCE OF CONCENTRATION ON CHEMICAL REACTIVITY AND LIGHT ABSORPTION

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SUMMARY

We have investigated the influence of the concentration of reducing agents on the light absorption and chemical reactivity with the reactions between (1) oxalic acid and chlorine, and (2) acetone and aqueous iodine, and have found that both the chemical reactivity and increased light absorption by the mixture diminish with the decrease in the concentration of the reducing agent.

We have also investigated the effect of the variation of the concentration of hydrochloric acid—a catalyst—on the light absorption by the mixture of acetone, hydrochloric acid and iodine and have found that the increase in the light absorption by the mixture diminishes from 713 Å° when 12N. HCl is used to 324 Å° when 0.17N. HCl is used. This result has established our theory regarding the influence of concentration on chemical reactivity and light absorption discussed in this paper.

With the advent of the modern spectroscopic researches much progress has been made on absorption and emission spectra of atoms and molecules and a new line of argument is now being given for the primary and secondary photochemical reactions. The primary effect of absorption in the case of continuous spectrum in a gas is always a dissociation into atoms or radicals, and in nearly all photochemical discussions, this atomic mechanism of reaction chains has been obviously preferred to the energetic, in which the chains are propagated by excited or, in other words, strongly vibrated molecules. Victor Henri (8) has shown that the absorption spectra of a number of molecules pass from a fine structure to a blurred one consisting of different bands. The condition of the molecule in which the bands are diffused has been called the predissociation stage, and in generalizing the results in the diffuse regions, he has stated that the molecules become chemically active in this region.

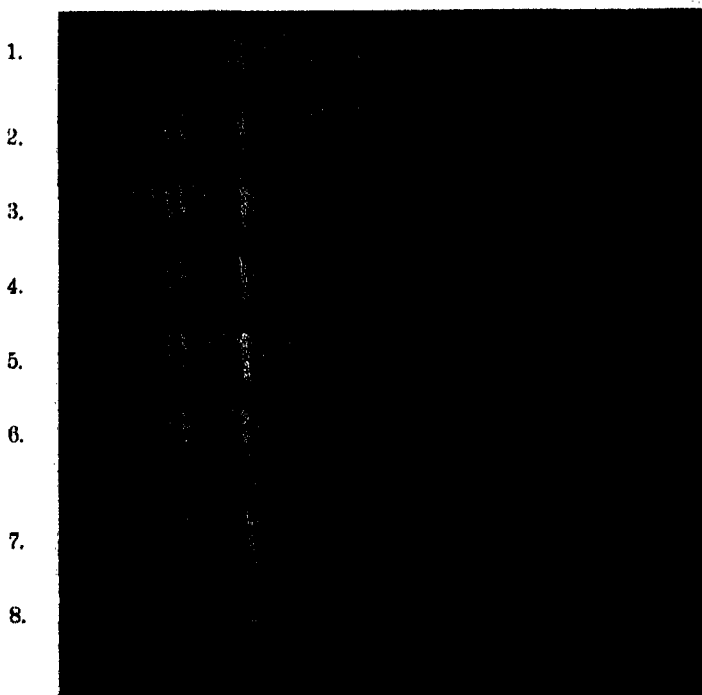
It appears, therefore, that an increase in the chemical reactivity by increase of temperature is associated with an increased light absorption. Dhar and Bhattacharya (7) made an advance on this problem by showing that, besides temperature—a physical agent—a chemical reagent capable of making a molecule chemically reactive, also shows an increase in light absorption.

We have now taken up this problem in order to find out if the concentration of the chemical reagent, which makes the molecules of the other reacting component more reactive, has any effect on the light absorption.

In this communication we are submitting the results obtained with the reactions between (1) oxalic acid and chlorine, and (2) acetone and iodine.

(1) *Oxalic acid and chlorine*.—The reaction between oxalic acid and chlorine was first investigated by Bhattacharya and Dhar (2) who determined its kinetics and the order in the dark as well as in the visible and infra-red radiations. This reaction is extremely rapid in the dark, but it has a measurable velocity in the presence of hydrochloric acid. The effect of the addition of hydrochloric acid seems merely to be the depression of the oxalate ion concentration, the latter alone probably reacting with chlorine.

PLATE I



1. Copper arc.
2. $N/75 \text{ Cl}_2 + \text{Water}$
3. $(N/5 \text{ H}_2\text{C}_2\text{O}_4 + 1.7 \text{ N. HCl}) + \text{Water}$
4. $N/5 \text{ H}_2\text{C}_2\text{O}_4 + 1.7 \text{ N. HCl} + N/75 \text{ Cl}_2$
5. $(N/10 \text{ H}_2\text{C}_2\text{O}_4 + 1.7 \text{ N. HCl}) + \text{Water}$
6. $N/10 \text{ H}_2\text{C}_2\text{O}_4 + 1.7 \text{ N. HCl} + N/75 \text{ Cl}_2$
7. $(N/100 \text{ H}_2\text{C}_2\text{O}_4 + 1.7 \text{ N. HCl}) + \text{Water}$
8. $N/100 \text{ H}_2\text{C}_2\text{O}_4 + 1.7 \text{ N. HCl} + N/75 \text{ Cl}_2$

In order to study the effect of the concentration of oxalic acid on the increase in the light absorption by a mixture of oxalic acid and chlorine, we took the photographs using the E_3 type quartz spectrograph with copper arc as source of light. We determined also the velocity constant with each concentration of oxalic acid used. To see if any appreciable amount of reaction had taken place during the period of exposure, we performed the following experiment: The reactants were mixed in the quartz cell as for the absorption experiment and 5 c. c. of the mixture was added at once to potassium iodide solution, and the liberated iodine was titrated with standard hypo solution. The mixture was again prepared in the cell exposed to the arc (as for taking the absorption photographs) for 15 seconds, and 5 c.c. of the mixture was again titrated. There was no difference in the two titer values, which shows that no measurable reaction had taken place during the time the plate was exposed.

The following photograph and table show the variation of light absorption with the concentration of oxalic acid and also of the corresponding variation in the velocity of the reaction in the dark. It will be seen that the rate of the reaction goes hand in hand with the light absorption as we vary the concentration of oxalic acid.

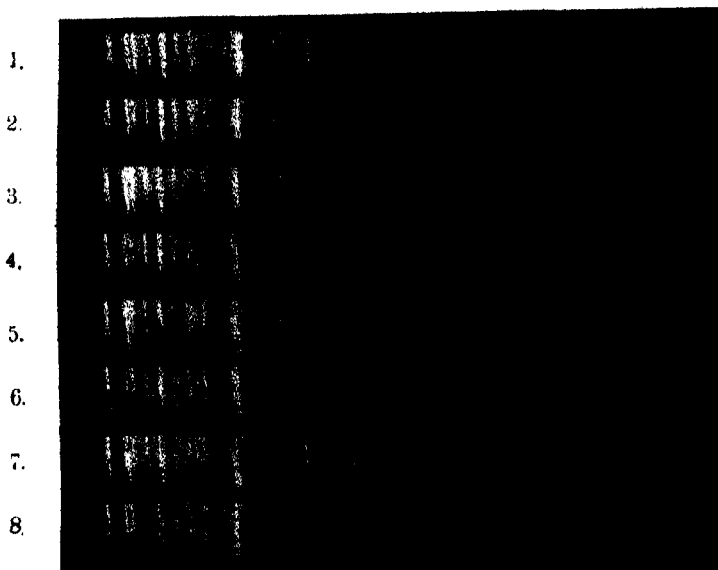
TABLE I

Constituents of the mixture.		Increase in the light absorption by the mixture.	Rate of reaction in the dark.
Concentration of Cl_2 and HCl	Concentration of $\text{H}_2\text{C}_2\text{O}_4$		
N/75 Cl_2 + 17 N HCl +	N/5 $\text{H}_2\text{C}_2\text{O}_4$	—	k_1
20 c c. + 10 c.c.	+ 10 c.c.	324 A°	0'00953
Ditto	+ N/10 $\text{H}_2\text{C}_2\text{O}_4$	254 A°	0'00672
	10 c.c.		
Ditto	+ N/100 $\text{H}_2\text{C}_2\text{O}_4$	110 A°	Negligible.
	10 c.c.		

As it has already been mentioned, hydrochloric acid acts as a retarder of the reaction between oxalic acid and chlorine. To study the effect of the variation of the concentration of hydrochloric acid on the absorption spectrum of oxalic acid, we took the photographs (see Plate II). The photographs reveal that the light absorption by oxalic acid which is due to the oxalate ions

decreases on the addition of hydrochloric acid to oxalic acid and that this decrease in light absorption varies with the concentration of hydrochloric acid.

PLATE II



1. Copper arc.
2. $N/5 \text{ H}_2\text{C}_2\text{O}_4 + \text{Water}$
3. $12.0 \text{ N. HCl} + \text{Water}$
4. $12.0 \text{ N. HCl} + N/5 \text{ H}_2\text{C}_2\text{O}_4$
5. $6.0 \text{ N. HCl} + \text{Water}$
6. $6.0 \text{ N. HCl} + N/5 \text{ H}_2\text{C}_2\text{O}_4$
7. $N/5.9 \text{ HCl} + \text{Water}$
8. $N/5.9 \text{ HCl} + N/5 \text{ H}_2\text{C}_2\text{O}_4$

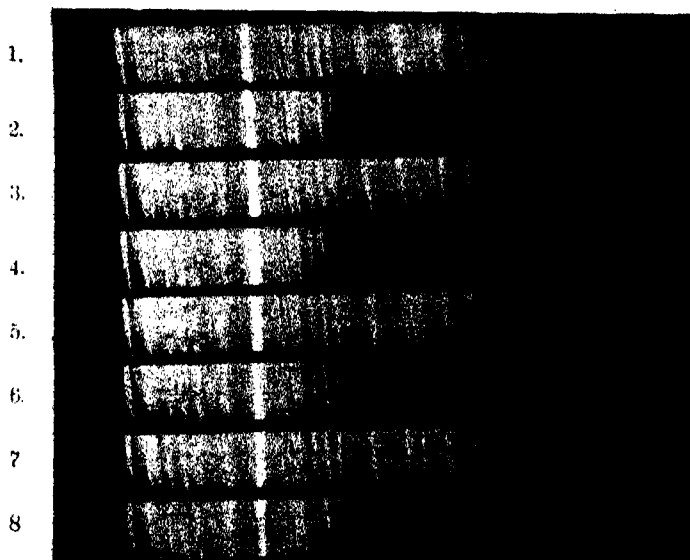
(2) *Acetone and iodine*.—It was shown by Dawson and his pupils (4) that iodine acts slowly on an aqueous solution of acetone, that the reaction is catalytically accelerated by hydrogen ions, and that the acceleration depends on hydrogen ion concentration. Dhar (6) showed that the reaction was accelerated to a very marked extent by light.

Bhattacharya and Dhar (1) investigated the photochemical reaction in the visible and infra-red radiations, and later (3) they found that a mixture of acetone and aqueous solution of iodine showed a greater light absorption than either acetone or iodine, taken separately.

We have studied the effect of the concentration of acetone on the absorption spectra and the velocity of the reaction between acetone and an aqueous solution of iodine in the presence of hydrochloric acid. The Plate III shows the effect of the variation of concentration of acetone on the light absorption of the mixture. The

titer values showed that no chemical change had taken place during the period of exposure.

PLATE III



1. Cu arc.
2. N/340 I_2 + Water
3. (1% acetone + 1.7 N. HCl) + Water
4. (1% acetone + 1.7 N. HCl) + N/340 I_2
5. (0.5% acetone + 1.7 N. HCl) + Water
6. (0.5% acetone + 1.7 N. HCl) + N/340 I_2
7. (0.1% acetone + 1.7 N. HCl) + Water
8. (0.1% acetone + 1.7 N. HCl) + N/340 I_2

The following table shows the variation of the absorption increase and the velocity of the dark reaction with the change in the concentration of acetone. The results confirm the view that, with the variation of the concentration of the reducing agent, both the rate of reaction and light absorption are equally affected.

TABLE II

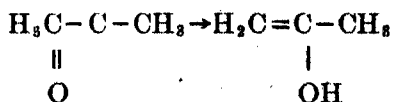
Constituents of the mixture. Concentration of I_2 and HCl.	Concentration of acetone.	Increase in the light absorption by the mixture.	Rate of reaction in the dark.
N/340 I_2 , + 1.7 N HCl. 10 c. c. + 5 c. c.	+ 1 % acetone + 5 c.c.	508 A° (excluding partial absorption)	K_1 0.02815
Ditto	0.5 % c.c.	508 A°	0.01355
Ditto	0.1 % c.c.	Nil	0.003265

DISCUSSION

From the photographs, it is evident that complete absorption by the reacting mixtures begins from a longer wave-length than that by the reacting components, and that the increase in the concentration of the reducing agent leads to more light absorption by the mixture. The photographs reveal also the fact that with a very dilute solution of the reducing agent, the mixture does not show any enhanced absorption, and that at these concentrations, the velocity of the chemical reactions also is almost negligible as shown in the Tables I and II. Hence, we are of opinion that enhanced light absorption by the mixture goes hand in hand with the chemical reactivity. It may, therefore, be argued that the reactivity of the mixture is preceded by the formation of an additive product with the weakening of the binding forces and increased light absorption. It has been postulated that in the photochemical reactions involving the halogens the primary change is the atomisation of the halogen molecules, but the foregoing results show that the first stage is the formation of an additive compound, perhaps of an unstable nature and having an increased light absorption, and this leads to the weakening of the binding forces of the halogen molecules.

In this connection it would be of interest to note the effect of a catalyst on the absorption spectrum of a reaction.

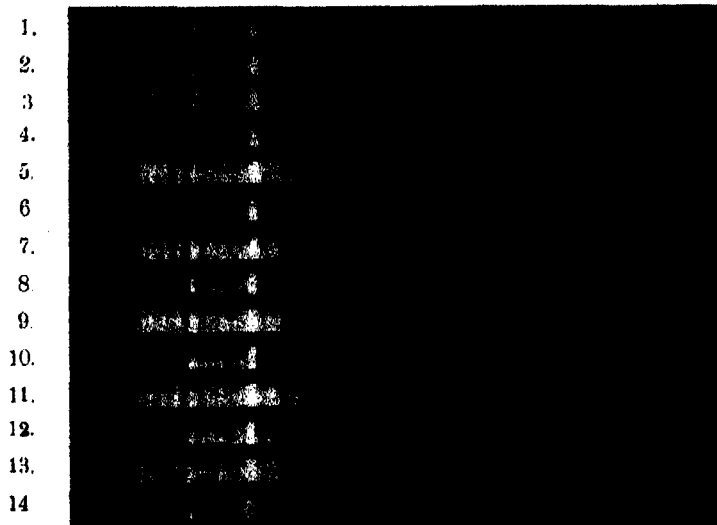
It has been shown by Dawson and others that the reaction between acetone and iodine is catalysed by hydrogen ions. The effect of the catalyst is only to increase the velocity of enolisation of acetone, which takes place according to the following scheme:



This increase in the velocity is directly proportional to the concentration of hydrogen ions. This led us to think that in view of the fact that the increase in the chemical reactivity of a substance is followed by a marked increase in its absorption spectrum, this absorption increase, being directly dependent on the velocity of the reaction, should vary with the variation in the concentration of hydrogen ions. We photographed, therefore, the absorption spectra of the mixture of acetone and iodine using a wide range of the concentration of hydrochloric acid, *viz.*, from 12.0N to 0.17N. The results are recorded on Plate IV. The spectra show a regular decrease in the absorption as the concentration of hydrochloric acid decreases. The absorption spectra with 12.0N. HCl and 6.0N. HCl seem to be very similar (though there does exist a very minute difference between the two) which is probably because 12.0N

hydrochloric acid which is merely pure saturated solution of HCl has very small ionic activity.

PLATE IV



1. Copper arc.
2. N/340 I₂ + Water
3. (12.0 N. HCl + 1% acetone) + Water
4. (12.0 N. HCl + 1% acetone) + N/340 I₂
5. (6.0 N. HCl + 1% acetone) + Water.
6. (6.0 N. HCl + 1% acetone) + N/340 I₂
7. (3.0 N. HCl + 1% acetone) + Water
8. (3.0 N. HCl + 1% acetone) + N/340 I₂
9. (1.7 N. HCl + 1% acetone) + Water
10. (1.7 N. HCl + 1% acetone) + N/340 I₂
11. (0.85 N. HCl + 1% acetone) + Water
12. (0.85 N. HCl + 1% acetone) + N/340 I₂
13. (0.17 N. HCl + 1% acetone) + Water
14. (0.17 N. HCl + 1% acetone) + N/340 I₂

These results thus lend a very strong and unmistakable evidence in support of our view that the increase in the light absorption is the direct result of the increased chemical reactivity of the molecules

In conclusion, we should like to emphasize that our experimental results and photographs, with different concentrations of the reducing as well as catalysing agents, have established the fact that increased chemical reactivity of molecules is always accompanied by increased light absorption, and with the fall in chemical

reactivity due to lower concentration of the reducing or catalysing agent, the light absorption by the mixture also decreases.

Further work in this connection is in progress in these laboratories.

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KINETICS OF SLOW COAGULATION OF SOLS BY ELECTROLYTES

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SUMMARY

In this paper the kinetics of slow coagulation of the positively charged sols of ferric phosphate and ferric hydroxide (Kreke's method) of different degrees of purities and concentrations by both monovalent and bivalent anions have been investigated. In the case of impure sols of ferric phosphate the rate of slow coagulation with potassium sulphate has a S-shaped character, which has a tendency to vanish with increasing purity of the sol. With potassium chloride the coagulation-time curve is asymptotic for an impure sol which gradually becomes S-shaped for pure sols. If the concentrations of either potassium chloride or potassium sulphate are increased, the coagulation becomes rapid and the coagulation-time curve has a tendency to become asymptotic. In the case of ferric hydroxide-sols obtained by Kreke's method the coagulation-time curve for all purities and concentrations of the sols is of asymptotic nature. These results are in conformity with the conclusions of Ghosh on the nature of slow coagulation which has been described as the contribution of two speeds (1) velocity of charge neutralisation and (2) that of the aggregation of the subsequently discharged particles.

In a previous publication, Ghosh (3) has critically summarized all the results obtained on the process of slow coagulation of different sols by electrolytes. It has been reported there on theoretical considerations that the character of slow coagulation of a sol by an electrolyte is greatly dependent on the nature (lyophile or lyophobic) of the sol coagulated. It is well-known that a sol of ferric phosphate has a high viscosity, yields a gel on continued dialysis, and produces either a gel or a gelatinous precipitate on coagulation with electrolytes. On the other hand, ferric hydroxide sol obtained by dropping a concentrated solution of ferric chloride to boiling water has a viscosity very similar to that of water and yields precipitates on coagulation which are not gelatinous. In other words, these two sols have different properties as far as their viscosities and the capabilities of yielding gels are concerned. The following experiments were, therefore, carried out with these sols possessing different properties, to investigate the nature of slow coagulation.

EXPERIMENTAL

The method adopted for measuring the rate of coagulation was as follows : Six or more test tubes containing known amount of a sol made up to 5 c.c. were taken. A definite volume of electrolyte capable of producing slow coagulation was also made up to 5 c.c. in another set of six test tubes. The sol and the electrolytes were next mixed together and the time noted. At different intervals

of time, one test tube after the other was taken out and centrifuged at a constant revolution of 2,000 per minute for two minutes. The amount of sol left uncoagulated, which was left in the supernatant liquid, was analysed for iron content by the usual method of reduction and titration with standard permanganate solution.

Ferric phosphate sol. It was prepared by the addition of sodium-di-hydrogen phosphate to a concentrated solution of ferric chloride and was kept for dialysis.* Different samples of the sol (A, B, C and D) at various stages of dialysis were taken out for investigation. The results on the slow coagulation of this sol with potassium chloride and potassium sulphate are given below:

TABLE I
Sol A coagulated by K_2SO_4 at $35^\circ C$

Final concentration of K_2SO_4 0.0032 N.	Time in minutes.	0	10	20	30	40	50
	Amount of iron left as sol in milliatom	0.072	0.068	0.066	0.064	0.063	0.062
Final concentration of K_2SO_4 0.0040 N.	Time in minutes.	0	11½	20	30	40	50
	Amount of iron left as sol in milliatom.	0.072	0.066	0.044	0.026	0.020	0.018
Final concentration of K_2SO_4 0.0048 N.	Time in minutes.	0	8	16	24	32	43.5
	Amount of iron left as sol in milliatom.	0.072	0.014	0.010	0.008	0.007	0.006
Final concentration of K_2SO_4 0.0064 N.	Time in minutes.	0	10	20	30	40	50
	Amount of iron left as sol in milliatom.	0.144	0.140	0.136	0.134	0.132	0.130
Final concentration of K_2SO_4 0.0072 N.	Time in minutes.	0	8	16	24	32	48
	Amount of iron left as sol in milliatom.	0.144	0.136	0.122	0.098	0.064	0.052
Final concentration of K_2SO_4 0.0080 N.	Time in minutes.	0	6	10	15	20	25
	Amount of iron left as sol in milliatom.	0.144	0.139	0.130	0.038	0.034	0.033
Final concentration of K_2SO_4 0.0088 N.	Time in minutes.	0	5	10	15	20	25
	Amount of iron left as sol in milliatom.	0.144	0.060	0.034	0.030	0.028	0.027

* This method was employed for obtaining sols of different purities.

TABLE II

Sol B coagulated by K_2SO_4 at 35°C.

Final concentration of K_2SO_4 0.0072 N.	Time in minutes.	0	10	20	30	40	50
	Amount of iron left as sol in milliatom.	0.044	0.044	0.043	0.043	0.043	0.043
Final concentration of K_2SO_4 0.0080 N.	Time in minutes.	0	10	20	30	40	50
	Amount of iron left as sol in milliatom.	0.044	0.044	0.043	0.042	0.038	0.022
Final concentration of K_2SO_4 0.0088 N.	Time in minutes.	0	10	20	30	40	50
	Amount of iron left as sol in milliatom.	0.044	0.042	0.030	0.016	0.008	0.005
Final concentration of K_2SO_4 0.0096 N.	Time in minutes.	0	8	16	24	32	40
	Amount of iron left as sol in milliatom.	0.044	0.033	0.010	0.006	0.004	0.004
Final concentration of K_2SO_4 0.0104 N.	Time in minutes.	0	5	10	15	20	25
	Amount of iron left as sol in milliatom.	0.044	0.014	0.009	0.006	0.004	0.003

TABLE III

Sol C coagulated by K_2SO_4 at 35°C.

Final concentration of K_2SO_4 0.0092 N.	Time in minutes.	0	10	20	30	40	50
	Amount of iron left as sol in milliatom.	0.048	0.047	0.044	0.040	0.038	0.036
Final concentration of K_2SO_4 0.0096 N.	Time in minutes.	0	10	20	30	40	50
	Amount of iron left as sol in milliatom.	0.048	0.044	0.031	0.020	0.014	0.012
Final concentration of K_2SO_4 0.0100 N.	Time in minutes.	0	10	20	30	40	50
	Amount of iron left as sol in milliatom.	0.048	0.036	0.020	0.012	0.010	0.009

Final concentration of K_2SO_4 0.0104 N.	Time in minutes	0	5	10	15	20	25
	Amount of iron left as sol in milliatom.	0.048	0.024	0.012	0.008	0.007	0.006
Final concentration of K_2SO_4 0.0112 N.	Time in minutes.	0	10	20	30	40	50
	Amount of iron left as sol in milliatom.	0.096	0.096	0.096	0.096	0.096	0.096
Final concentration of K_2SO_4 0.0120 N.	Time in minutes.	0	10	20	30	40	50
	Amount of iron left as sol in milliatom.	0.096	0.094	0.086	0.046	0.039	0.034
Final concentration of K_2SO_4 0.0128 N.	Time in minutes.	0	8	16	24	32	40
	Amount of iron left as sol in milliatom.	0.096	0.092	0.040	0.028	0.024	0.021
Final concentration of K_2SO_4 0.0136 N.	Time in minutes.	0	5	10	15	20	25
	Amount of iron left as sol in milliatom.	0.096	0.044	0.020	0.017	0.015	0.014

TABLE IV

Sol D coagulated by K_2SO_4 at 35°C.

Final concentration of K_2SO_4 0.0040 N.	Time in minutes.	0	10	20	30	40	50
	Amount of iron left as sol in milliatom.	0.047	0.047	0.047	0.047	0.047	0.047
Final concentration of K_2SO_4 0.0044 N.	Time in minutes.	0	10	20	30	40	50
	Amount of iron left as sol in milliatom.	0.047	0.032	0.021	0.016	0.014	0.012
Final concentration of K_2SO_4 0.0048 N.	Time in minutes.	0	8	16	24	32	40
	Amount of iron left as sol in milliatom.	0.047	0.028	0.014	0.008	0.006	0.005

TABLE V

Sol B coagulated by KCl at 35°C.

Final concentration of KCl	Time in minutes.	0	10	20	30	40	50
0.0040 N.	Amount of iron left as sol in milliatom.	0.044	0.043	0.042	0.041	0.040	0.040
Final concentration of KCl	Time in minutes.	0	10	20	30	40	50
0.0048 N.	Amount of iron left as sol in milliatom.	0.044	0.043	0.040	0.036	0.028	0.020
Final concentration of KCl	Time in minutes.	0	8	16	20	24	32
0.0056 N.	Amount of iron left as sol in milliatom	0.044	0.042	0.036	0.030	0.025	0.018
Final concentration of KCl	Time in minutes.	0	8	16	24	32	40
0.0072 N.	Amount of iron left as sol in milliatom.	0.044	0.036	0.025	0.017	0.012	0.009
Final concentration of KCl	Time in minutes.	0	6	12	18	25	30
0.0088 N.	Amount of iron left as sol in milliatom.	0.044	0.024	0.014	0.010	0.007	0.006
Final concentration of KCl	Time in minutes.	0	5	10	15	20	25
0.0104 N	Amount of iron left as sol in milliatom.	0.044	0.012	0.008	0.006	0.004	0.003

TABLE VI

Sol C coagulated by KCl at 35°C

Final concentration of KCl	Time in minutes	0	10	20	30	40	50
0.0024 N.	Amount of iron left as sol in milliatom.	0.048	0.048	0.047	0.048	0.044	0.038
Final concentration of KCl	Time in minutes.	0	10	20	30	40	50
0.0032 N.	Amount of iron left as sol in milliatom.	0.048	0.046	0.040	0.024	0.016	0.014

Final concentration of KCl 0.0040 N.	Time in minutes.	0	8	16	24	32	40
	Amount of iron left as sol in milliatom.	0.048	0.038	0.018	0.010	0.008	0.007
Final concentration of KCl 0.0084 N.	Time in minutes.	0	5	10	15	20	25
	Amount of iron left as sol in milliatom.	0.048	0.024	0.014	0.010	0.007	0.005
Final concentration of KCl 0.0032 N.	Time in minutes.	0	10	20	30	40	50
	Amount of iron left as sol in milliatom.	0.096	0.096	0.096	0.096	0.096	0.096
Final concentration of KCl 0.0040 N.	Time in minutes.	0	10	20	30	40	50
	Amount of iron left as sol in milliatom.	0.096	0.096	0.095	0.094	0.090	0.078
Final concentration of KCl 0.0048 N.	Time in minutes.	0	10	20	30	40	50
	Amount of iron left as sol in milliatom.	0.096	0.095	0.094	0.085	0.060	0.038
Final concentration of KCl 0.0064 N.	Time in minutes.	0	10	20	30	40	50
	Amount of iron left as sol in milliatom.	0.096	0.094	0.030	0.022	0.017	0.014
Final concentration of KCl 0.0080 N.	Time in minutes.	0	6	12	18	24	30
	Amount of iron left as sol in milliatom.	0.096	0.028	0.014	0.012	0.011	0.010

TABLE VII

Sol D coagulated by KCl at 35°C.

Final concentration of KCl 0.0024 N.	Time in minutes.	0	10	20	30	40	50
	Amount of iron left as sol in milliatom.	0.047	0.047	0.047	0.047	0.047	0.047
Final concentration of KCl 0.0032 N.	Time in minutes.	0	10	20	30	40	50
	Amount of iron left as sol in milliatom.	0.047	0.047	0.046	0.028	0.022	0.018

Final concentration of KCl 0.0048 N	Time in minutes.	0	6	12	18	30	40
	Amount of iron left as sol in milliatom	0.047	0.046	0.016	0.008	0.006	0.005
Final concentration of KCl 0.0056 N.	Time in minutes.	0	5	10	15	20	30
	Amount of iron left as sol in milliatom	0.047	0.020	0.008	0.006	0.005	0.003
Final concentration of KCl 0.0048 N.	Time in minutes.	0	10	20	30	40	50
	Amount of iron left as sol in milliatom.	0.094	0.094	0.093	0.092	0.090	0.080
Final concentration of KCl 0.0056 N.	Time in minutes.	0	10	20	30	40	50
	Amount of iron left as sol in milliatom.	0.094	0.094	0.090	0.060	0.044	0.034
Final concentration of KCl 0.0072 N.	Time in minutes.	0	5	10	20	30	40
	Amount of iron left as sol in milliatom.	0.094	0.093	0.060	0.032	0.020	0.017
Final concentration of KCl 0.0080 N.	Time in minutes.	0	6	12	18	25	35
	Amount of iron left as sol in milliatom.	0.094	0.056	0.032	0.022	0.018	0.015

Ferric hydroxides sol: This sol was obtained by the Krecke's method and the results on its slow coagulation by both monovalent and bivalent anions at different stages of dialysis (sols 1, 2 and 3) are given below :

TABLE VIII

Sol 1 coagulated by K_2SO_4 at $35^\circ C$.

Final concentration of K_2SO_4 0.0088 N.	Time in minutes.	0	10	20	30	40	50
	Amount of iron left as sol in milliatom.	0.064	0.059	0.056	0.055	0.054	0.055
Final concentration of K_2SO_4 0.0092 N.	Time in minutes.	0	5	10	20	30	40
	Amount of iron left as sol in milliatom.	0.064	0.050	0.044	0.038	0.036	0.035

Final concentration of K_2SO_4 0.0096 N.	Time in minutes.	0	5	10	20	30	40
	Amount of iron left as sol in milliatom.	0.064	0.028	0.025	0.024	0.023	0.022

TABLE IX

Sol 2 coagulated by K_2SO_4 at 35°C.

Final concentration of K_2SO_4 0.0064 N	Time in minutes.	0	15	30	45	50	60
	Amount of iron left as sol in milliatom.	0.094	0.092	0.090	0.089	0.088	0.088
Final concentration of K_2SO_4 0.0068 N.	Time in minutes.	0	6	12	18	24	35
	Amount of iron left as sol in milliatom.	0.094	0.080	0.070	0.064	0.060	0.054
Final concentration of K_2SO_4 0.0072 N.	Time in minutes.	0	5	10	15	20	30
	Amount of iron left as sol in milliatom.	0.094	0.068	0.050	0.040	0.034	0.026

TABLE X

Sol 3 coagulated by K_2SO_4 at 35°C.

Final concentration of K_2SO_4 0.0064 N.	Time in minutes.	0	10	20	30	40	50
	Amount of iron left as sol in milliatom	0.092	0.090	0.088	0.087	0.086	0.085
Final concentration of K_2SO_4 0.0068 N.	Time in minutes.	0	8	15	24	32	48
	Amount of iron left as sol in milliatom.	0.092	0.084	0.079	0.074	0.070	0.064
Final concentration of K_2SO_4 0.0072 N.	Time in minutes.	0	6	12	18	24	35
	Amount of iron left as sol in milliatom.	0.092	0.008	0.006	0.005	0.004	0.003

TABLE XI

Sol 2 coagulated by KCl at 35°C.

Final concentration of KCl 0.0040 N.	Time in minutes.	0	10	20	30	40	50
	Amount of iron left as sol in milliatom.	0.094	0.090	0.086	0.082	0.080	0.078

Final concentration of KCl	Time in minutes.	0	5	10	15	25	35
0.0048 N.	Amount of iron left as sol in milliatom.	0.094	0.086	0.080	0.074	0.065	0.056
Final concentration of KCl	Time in minutes.	0	6	10	15	25	40
0.0056 N.	Amount of iron left as sol in milliatom.	0.094	0.050	0.039	0.030	0.022	0.016

TABLE XII

Sol 3 coagulated by KCl at 35°C.

Final concentration of KCl	Time in minutes.	0	15	30	45	60	
0.014 N.	Amount of iron left as sol in milliatom.	0.092	0.088	0.086	0.084	0.083	
Final concentration of KCl	Time in minutes	0	5	10	16	24	35
0.016 N.	Amount of iron left as sol in milliatom.	0.092	0.072	0.050	0.050	0.044	0.044
Final concentration of KCl	Time in minutes.	0	5	10	15	20	30
0.018 N.	Amount of iron left as sol in milliatom.	0.092	0.052	0.042	0.036	0.032	0.026

The compositions of ferric phosphate and ferric hydroxide sols are given below:

Ferric phosphate sols :—

Sol A :— 0.1400 gram atom of iron, 0.1030 gram radical of phosphate and 0.2930 gram ion of chlorine per litre.

Sol B :— 0.0880 gram atom of iron, 0.0827 gram radical of phosphate and 0.0286 gram ion of chlorine per litre.

Sol C :— 0.0960 gram atom of iron, 0.0806 gram radical of phosphate and 0.0188 gram ion of chlorine per litre.

Sol D :— 0.0940 gram atom of iron, 0.0789 gram radical of phosphate and 0.0138 gram ion of chlorine per litre.

Ferric hydroxide sols :—

Sol I :— 0.0640 gram atom of iron and 0.0155 gram ion of chlorine per litre

Sol II :— 0.0949 gram atom of iron and 0.0084 gram ion of chlorine per litre.

Sol III :— 0.0920 gram atom of iron and 0.00181 gram ion of chlorine per litre.

The results obtained on the slow coagulation of ferric phosphate and ferric hydroxide sols by both monovalent and bivalent anions show that the nature of slow coagulation is different in these two cases. The character of slow coagulation for ferric phosphate sols is autocatalytic; it is highly pronounced with impure sols, and gradually vanishes with pure sols in the presence of potassium sulphate, but becomes prominent in the presence of potassium chloride. In the case of ferric hydroxide sols, however, we do not find the existence of the autocatalytic nature of slow coagulation either by potassium chloride or by potassium sulphate; this holds good for all the purities of sols investigated in this paper.

In explaining the mechanism of slow coagulation, especially in those cases where the coagulation develops an autocatalytic nature, various theories have been put forward by different investigators. Freundlich (1) and Ghosh (2) consider this autocatalytic process of aggregation as a result of partial de-electrification of colloid particles by the addition of the oppositely charged ion. Smoluchowski (6) concluded that the S-shaped curve obtained for certain cases of slow coagulation is due to the defect in the methods employed for determining the rate of aggregation of a colloid in its slow coagulation. If it is carried out either by viscosity measurement or by the method employed by Paine (5), the formation of a S-shaped curve is a necessary consequence of the method employed. It is also true that the shaking has a considerable effect in the process of coagulation of a sol; it sometimes acts as a broom for the de-electrified colloid particles. It should be here stated that the method employed in this paper may be open to objection that the sol is centrifuged after a certain state of aggregation. It has however been noted that a sol of ferric phosphate or ferric hydroxide after it has stood undisturbed for eight minutes or more on the addition of an electrolyte and then centrifuged for two minutes, the effect of shaking on the coagulation of the sol is not much remarkable. It was also casually observed that the effect of shaking is significant with impure sols only, while in the case of pure sols it is insignificant. It may also be noted here that this method is different from that followed by Paine who subjected the same sol of copper (mainly copper hydroxide) to repeated centrifuging at different intervals of time, which necessarily and considerably increased the shaking effect on the phenomenon of slow coagulation.

In a recent communication, Ghosh examined the various theories regarding the process of slow coagulation and came to the conclusion that the behaviour of different sols, in the region of their slow coagulation, cannot be explained in all cases. It may be possible to explain the existence of a S-shaped curve for the process of slow coagulation on the view of partial discharge of colloid particles. But the development of asymptotic types of curves observed in the slow coagulation of some sols cannot be explained,

It has already been shown (3) that slow coagulation of a sol by an electrolyte is a contribution of two processes, *viz.*, (1) the charge neutralisation to a minimum potential and (2) cohesion of such discharged particles due to their impact. It will be seen from these considerations that in the region of slow coagulation the added electrolyte is always small, and if the aggregation tendency of colloid particles is comparatively less, the whole speed of aggregation, which is a joint contribution of two processes already described, will be characterized by the development of a S-shaped curve. If, however, the colloid particles are of lyophobic character, the process of cohesion to form aggregates is highly pronounced, and consequently the rate of aggregation during the process of slow coagulation will be determined by the speed of de-electrification of the charged colloid particles by the added ions.

Our results on the determination of the rate of slow coagulation of the ferric phosphate and ferric hydroxide sols by different electrolytes show that the speed of aggregation in the former is a S-shaped one, whilst that for ferric hydroxide sols the curves are asymptotic. The sol of ferric phosphate has close resemblance to many lyophilic sols, whilst that of ferric hydroxide (prepared by Krecke's method) is a typical lyophobic one. So far as the property of viscosity is considered, we have found that a ferric phosphate sol has a considerable high viscosity as compared with that of ferric hydroxide (prepared by Krecke's method).

The sols of ferric phosphate, when they are sufficiently impure, contain greater amounts of stabilising agents, and require greater amounts of electrolyte to coagulate them than the sols which are pure. From all what has been said before, the de-electrification of colloid particles from an impure sol will be a slower process than that of the colloid particles from a pure sol. In other words, the speed of de-electrification of colloid particles affected by the addition of electrolyte will increase with the increasing purity of the sol, as it is expected that the electrical charge on the colloid particles will diminish with the continuous removal of the stabilizing ions present in a sol. It has already been reported by Gore and Dhar (4) that the electrical charge on the colloidal particles has a tendency to decrease with the progressive dialysis of the sol. It will be seen from the calculations of Ghosh that the speed of de-electrification of colloid particles from a sol is more rapid with a bivalent coagulating ion than with a monovalent ion. For an impure sol of ferric phosphate, speed of the de-electrification of colloid particles carried on with sulphate ion is slow in comparison with that for a pure sol. Consequently, the speed of de-electrification of an impure colloid of ferric phosphate is comparable with the speed of aggregation of the discharged colloid particles, which necessarily develops a S-shaped curve. In the case of potassium chloride the speed of de-electrification of colloid particles from an impure sol is very small in comparison with the speed of aggregation of the discharged colloid particles and, therefore, the final speed of slow coagulation is determined by the

process of de-electrification by monovalent chloride ions. When, however, the purer sols are taken for investigation, the speed of de-electrification of colloid particles by bivalent SO_4^{--} ion from potassium sulphate rapidly increases, becomes too great in comparison with the speed of aggregation of the discharged colloid particles, with the result that the curves for slow coagulation are no more S-shaped for pure sols. In the case of KCl, however, the speed of de-electrification of colloid particles of the sol increases with the increasing purity of the sol, and finally becomes comparable with the speed of aggregation of the discharged colloid particles, which is always characterized by a S-shaped curve for slow coagulation. Our results on process of the slow coagulation of a sol of definite purity either by potassium chloride or potassium sulphate of various concentrations can be explained by similar reasoning.

In the case of ferric hydroxide sol (prepared by Krecke's method) the rate of aggregation of colloid is always too rapid to be compared with that of de-electrification of colloid particles at any stage of purity. The S-shaped curve has not been observed at any stage of purity for this sol of whatever concentration of potassium chloride or potassium sulphate.

Our results are, therefore, in conformity of the view that the slow coagulation of the sol is a contribution of two processes, *viz.*, de-electrification and subsequent aggregation, the speeds of both of which determine the whole process of slow coagulation.

We may also suggest that those sols which have a tendency to lyophilic behaviour will develop a S-shaped coagulation-time curve for the process of slow coagulation at a suitable purity, whilst the sol of lyophobic character will develop an asymptotic curve for their slow coagulation by any coagulating electrolyte

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THE RADION AND THE ELECTRO-MAGNETIC WHIRL

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SUMMARY

The author compares Sir Shah Sulaiman's Radion theory according to which Light and Matter are formed by rotating dipoles "binary stars", called Radions, and his own Whirl theory according to which Light and Matter are formed by certain axially symmetrical systems of Maxwell e.m. waves which he called e.m. whirls or simply Whirls.

This comparison of two theories is preceded by the discussion of the conditions of adequateness of a physical theory. Two schools of mind can be distinguished in this question. According to the one the purpose of Science is to *explain* the unfamiliar experience in terms of the familiar one by means of visual images taken from the latter, which the author called generally "models." According to the other, such an explanation is unattainable, and, therefore, the Science can only *correlate* the experience, and this can be done by an artificial system of mathematical symbols with *ad hoc* invented rules of operation.

Sir Shah and the author both associate themselves with the first school, but they choose their models differently.

The author gives the reasons why, in his opinion, the explanation of the physical world by means of models is important not only for the Science itself but also for the general progress of mankind, and why such an explanation should be attainable.

Then, the author gives the summary of Sir Shah's theory, mainly in Sir Shah's own words, and summarizes the general foundations and the principal conclusions of the Whirl theory. He recalls that the Whirl Theory of Light and Matter is entirely based upon Maxwell Electro-dynamics, and that according to this theory the classical, quantum and wave mechanical, and relativistic properties of Light and Matter are the necessary corollaries of the electro-magnetic properties of the Whirls.

Further, the author quotes verbatim Sir Shah's criticism of the whirl theory and gives the reasons why he considers this criticism invalid.

The author thinks that the chief advantage of the whirl theory is the singleness of its unifying principle; while Sir Shah must use electric charge, *and* inertial mass, *and* the Maxwell e.m. field, as independent fundamental conceptions, in the whirl theory the Maxwell Electro-dynamics in free space is the general foundation of the whole theory.

Then the author finds in the formal part of Sir Shah's theory certain difficulties which he thinks to be hardly surmountable, namely, for the description of the e.m. field of his Radions. Sir Shah uses the same solution of the Maxwell equations as the author himself used for the e.m. whirls ("the Japolsky solution" as Sir Shah calls it), but this solution does *not* correspond to the boundary conditions presented by Sir Shah's Radions.

In conclusion, the author expresses his appreciation of Sir Shah's contribution as a research in a new field. Especially he points out the importance of the part of Sir Shah's work where he

derives the Schroedinger and Heisenberg equations from the de Broglie and Planck relationships which are the necessary corollaries of the "Japolsky solution" which Sir Shah and the author are both using for their respective theories.

INTRODUCTION

Sir Shah Sulaiman in his recent paper* develops his Rotational Theory of Matter.

In this paper he refers in very kind terms to my work on Rotating Electromagnetic Waves and on Electromagnetic Whirls,† expounds part of my mathematical analysis and conclusions, and utilizes them for his own theory. He admits certain resemblance between my theory of Light and Matter as forms of Electromagnetic Whirls and his theory of Radions ("rotating binary stars"), which enables him to utilize part of my work for his own theory, but, at the same time, he points out the essential differences in our respective physical outlooks. He offers his criticism of my physical interpretations of Light and Matter and puts forward the reasons why his own interpretation should be more satisfactory. In a separate section (Section V) Sir Shah explains how the Heisenberg and Schroedinger equations can be easily derived from my conclusions which he also embodies in his theory.

It can be inferred from that section that an explanation of such a possibility lies in the fact that Wave Mechanics and Quantum Mechanics represent "mere rotational mechanics," and both theories are rotational theories.

The object of the present paper is to compare the principles underlying Sir Shah's physical outlook and my own, to point out certain errors in Sir Shah's criticism of the physical part of my theory, and certain unrevealed difficulties of his own theory, and, last but not least, to emphasize the importance of Sir Shah's contribution and particularly of certain general conclusions at which he arrives.

THE CONDITIONS OF ADEQUATENESS OF A PHYSICAL THEORY

We wish to feel at home in our World. We try, therefore, to explain it to ourselves in "familiar" terms, that is to say, in terms of our previous experience which has been fully assimilated by us.

What this experience can be?

First and foremost, it should be the observation of phenomena with which we come into immediate contact in our everyday life.

The visual representation of our familiar experience we can call the "models."

* The Mathematical Theory of a New Relativity, Chapter XV, By Sir Shah Sulaiman, *Proc. Acad. Sci., India*, (1937), Vol. VII, Part 2, p. 65.

† *Phil. Mag.*, Vol. XI, pp. 934-958; Vol. XX, pp. 427-468, and pp. 641-706 (1935); Vol XXII, pp. 537-581.

Thus, we naturally try to interpret our physical world by means of models taken from everyday life.

Is this possible?

This cannot be asserted or denied with certainty *a priori*. It must be tested.

It is quite possible that our experience in different domains of the physical world must differ so widely that its correlation can only be achieved by a purely artificial system of conceptions and symbols which may widely differ from the instruments of thought which we use for the interpretation of our familiar experience.

This conviction seems to prevail now in theoretical physics. Models are, therefore, in disfavour. At best they are looked upon as means of *illustration* but not of *explanation* of the phenomena. Any attempt to interpret the unfamiliar physical experience by means of familiar one, in other words, any attempt of *explanation* of physical phenomena is looked upon as doomed in advance, however simple and logical it may appear. On the other hand, a system of mathematical symbols with *ad hoc* invented rules of their operation appear to be accepted the more easily the remote they are from the usual methods of calculation.

Such an attitude is certainly legitimate and, in a way, "non-committal", for it is free from the *a priori* belief in the possibility of interpreting the unfamiliar experience in terms of a familiar one, in other words, of explaining the unfamiliar experience to our mind's satisfaction. In reality such an attitude is more than non-committal, it is an active disbelief in such a possibility, a sort of a militant defeatism.

Although this defeatism is fashionable, it is, nevertheless, still unacceptable to many who seek the synthesis of nature in generalizing images, vivid, though accurately measurable, and who will refuse to restrict themselves entirely to the "Nature's accountancy" by means of complicated and artificial, abstract mathematical symbols which spoil the eyesight and, to a considerable degree, blunt the imagination. They will try to find adequate models and will hope to succeed.

This hope is not entirely baseless.

General experience teaches us that we do not see what we fundamentally cannot explain. In other words, no sooner do we notice the facts than the ground is prepared in our minds to find for them a place in our system of previous experience.

This is certainly true with regard to the social and political phenomena and this appears to be also true in relation to our physical experience.

It appears that to explain the indirectly observable physical world in terms of familiar experience is not only possible for the above-stated reasons, but also very important for the development of human thought and, moreover, for the progress of human society.

If the indirectly observable physical world can be correlated only by means of an artificial machinery of symbols which is very remote in structure and operation from the mental machinery used for the perception of a more familiar world, then the mind of an investigator, the scientific mind, must get more and more divorced from the practical mind, that is, the mind of the great majority of mankind. The gap between the scientific and practical mind must then grow, and their interaction must necessarily diminish, and this, in its turn, must reduce the mutual influence between Science and the practical life. With this must grow departmentalism of Scientists and their inability to understand each other.

On the other hand, if the unfamiliar experience *can* be expressed in terms of familiar experience, the connection between Science and Life will become closer with the progress of Science, and the connection between different branches of human knowledge will also become closer.

This fundamental conviction inspired my work on Electro-magnetic Whirls. I expressed my attitude in the following terms* :—

"This renouncing of the macroscopic models would be the right way to follow for the theory of microscopic phenomena, if the *only purpose* of science were to work but a convenient representation of quantitative relationships between the various sides of our experience, so as to enable us to foresee and to some extent control it, for by means of a well chosen system of symbols we can represent simultaneously, and in a compact and accurate way, much larger complexes than the most powerful imagination can put in a simultaneously contemplable visual picture.

"But the purpose of science is much wider: it is not only to enable us to foresee and to control the experience, but also to *understand* it, which means to construct from it a wide picture of the universe around us which would satisfy our mind.

"To attain this satisfaction all our mental faculties must take an active part in the construction of this picture, and among them our concrete vision must occupy a position which would be adequate to its general importance in our mental life.

"But our vision develops under the constant influence of our macroscopic experience, and so a picture of the universe around us, built of macroscopic models, would be for us more vivid and tangible than an abstract symbolic representation built by a skilful mathematician, however accurate and elegant his system of symbols may be.

"Therefore the success of the abstract representation of the microscopic world, which has been already achieved by Wave Mechanics, and the continuous progress which it is making, must not be considered as a reason for ceasing to try to find the macroscopic models which would be suitable as bricks for building our picture of the world of elementary particles.

"The laws governing the macroscopic models chosen for this purpose must be accurately known and expressible in a simple way. At the present stage of our knowledge the most suitable models in this respect will be those which are based on macroscopic electromagnetic phenomena in free space—in other words, models representing systems of Maxwell's electromagnetic waves in free space, of directly measurable dimensions."

Bertrand Russell wrote me about my papers, "My prejudices are on your side."

Professor Dingle wrote to the effect that no theory can *explain* phenomena but can only help to *correlate* them. The attitude of these two philosophers is remarkably characteristic of the two trends of thought that they represent.

Sir Shah Sulaiman is apparently convinced, in common with me, that the physical world can still be interpreted in terms of models, but we choose our models differently. Sir Shah sees them as rigid corpuscles, while I regard them as systems of electro-magnetic waves.

The choice of models must depend on the contents of familiar experience and must, therefore, alter with time. Consequently, the "prejudices" in Bertrand Russell's sense should have something to do with it. However, I think that for a given historic period the choice of models can be made not only by prejudices but on rational grounds.

I think that in the light of present-day knowledge and experience, not only scientific but also popular, the conception of electro-magnetic waves is at least not less elementary than the conception of a miniature "billiard ball" or of a charged rigid corpuscle.

I cannot help feeling that Sir Shah Sulaiman's adherence to the rigid corpuscles as elementary models can be explained to a considerable extent by the fact that he belongs to an earlier generation than I, and at the time when the foundations of his scientific outlook were formed, there was no wireless. Of course, the choice of models, however rationally selected, can be finally judged only by the agreement of their theoretical manifestations with experience.

SUMMARY OF SIR SHAH SULAIMAN'S THEORY OF LIGHT AND MATTER

According to Sir Shah Sulaiman's fundamental assumption—

"Light consists of swarms of discreet units, Newton's corpuscles, now called radions, with one addition that in its inner structure a radion consists of two components of equal and opposite charges (found to be of equal masses also) rotating round their common centre of gravity, which is moving forward with a uniform velocity. The translational and the rotational motions give it both the particle and wave aspects simultaneously, *e.g.*, both momentum and wave-length. Light then becomes an electro-magnetic system, creating and carrying its field with it. Maxwell :

equations follow naturally. It has been shown that such a system automatically propagates itself with the known velocity of light."*

One can infer from Sir Shah's paper that elementary particles of matter (electrons, protons, etc.) have a similar structure, although he does not say so explicitly. Sir Shah prefers to disclose his assumption with regard to Matter in a few remarks in which he formulates the difference between my "Whirl" theory and his "Radion" theory and states the reasons why the latter is more advantageous in his opinion.† There he clearly refers to the Radions as representing the proton and the electron. He does not show, however, in detail how the known properties of the electron and the proton are manifested in the Radion. On the other hand, he considers in detail the hydrogen atom and takes it as an example of a "binary star" or Radion, of which the world must consist in his interpretation.

To describe the electro-magnetic field produced by the Radions forming the Matter, Sir Shah uses the Maxwell equations in cylindrical co-ordinates, which he puts exactly in the same form in which I have put them in my paper on Rotating Electro-magnetic Waves,‡ and then uses my solutions, as he acknowledges in very kind terms. He refuses, however, to interpret these solutions as Electromagnetic Whirls but connects them with the Radions.

The principal result of these solutions which Sir Shah utilizes is that they imply the de Broglie relationship $uv=c^2$ (where u is the speed of phase propagation, v the speed of the particle, c the speed of light) and the Planck formula $E=h\nu$ (E the energy of the particle, h the Planck constant, and ν the frequency of waves) not as postulates but as corollaries which follow from them on the basis of Maxwell Electrodynamics. This has been found by me for the Whirls but Sir Shah thinks that this should be equally true for the e.m. fields of the Radions.

To describe the electro-magnetic field of the light waves, Sir Shah uses another solution of the Maxwell equation. In this solution the amplitudes have the form $\frac{A}{r}$ (where A is a constant, r a radial co-ordinate in the cylindrical co-ordinate system)

In 1924§ I considered the same solution, but rejected it as involving infinite intensity of the field at $r=0$, or at any rate a discontinuity of the field (charge) at certain radions. However, for Sir Shah it is not an obstacle, as charged particles constitute an integral part of his theory.

* Sir Shah Sulaiman, *loc. cit.*, p. 66.

† *Ib dem.*, p. 68. These remarks will be quoted later.

‡ *Phil. Mag.*, XIX, p. 936, equation (2). Compare it with Sir Shah's equations (43'2) and (43'3) on p. 69 of his above-cited paper.

§ *Zs. für physik.*, 54, p. 121 (1929). In 1936 I discussed this solution (*Nature*, 137, pp. 823 and 1031) in connection with Sir J. J. Thornton's theory of Light (*Nature*, 137, pp. 232 and 663).

SUMMARY OF THE WHIRL THEORY OF LIGHT AND MATTER*

According to this theory Light and Matter in all their varieties are forms of Maxwell electro-magnetic waves in free space, or using Sir William Bragg's expression, our Universe is "the Universe of Light."

The physical history of the world is its electro-magnetic history. Mathematically it can be fully described in terms of the components of the *electro-magnetic* vector as a function of four co-ordinates; three space co-ordinates and one time co-ordinate.† The Electro-Magnetic Vector is defined by three components of the vector itself (primary components) and three time derivatives of these components (secondary components). These six components are, however, not arbitrary. The primary and the secondary components are connected by the well-known Maxwell equations which we can for our immediate purpose write in the form

$$\begin{aligned}\frac{1}{c} \dot{\mathbf{S}} &= \mp \nabla \times \mathbf{P} \\ \frac{1}{c} \dot{\mathbf{P}} &= \pm \nabla \times \mathbf{S} \quad \dots \quad \dots \quad \dots \quad \dots \quad (4.1)\end{aligned}$$

where c is a world constant of the dimensions of speed (speed of light), \mathbf{P} and \mathbf{S} are the primary and secondary vector respectively, ∇ is the vectorial operator with the components $\frac{d}{dx}$, $\frac{d}{dy}$, and $\frac{d}{dz}$, in the Cartesian space co-ordinates xyz , the sign \times denotes vector multiplication.§

It is clear from (4.1) that the secondary vector can always be taken for the primary and then the primary will become the secondary.

When we use the upper signs in (4.1) we call the primary vector "electric" and the secondary "magnetic," and *vice versa* when we use the lower signs.

It can be proved purely mathematically from the elementary properties of vectors that *in free space*, that is to say, in the absence of discontinuities of the field ("charges") the Maxwell electro-magnetic field must constantly vary in space and in time.§

* Japolsky, N. S., *Phil. Mag.*, Vol. XIX, pp. 934-958, Vol. XX, pp. 417-468 (1935), Vol. XXII, pp. 537-581 (1936).

† For the sake of continuity of the discussion the well-known foundations of Maxwell's theory will be briefly summarised here.

§ The sign would mean Scalar multiplication. The operators ∇ , $\nabla \cdot$ and $\nabla \times$ are more often called grad., div. and curl. or rot. respectively.

§ Vector analysis gives a well-known relationship

$$\nabla \times \nabla \times = \nabla \nabla \cdot - \nabla \cdot \nabla$$

where \cdot denotes Scalar multiplication. On the other hand Gauss's theorem gives $\nabla \cdot \mathbf{E} = 4\pi \rho$ and $\nabla \cdot \mathbf{B} = 0$ where \mathbf{E} and \mathbf{B} are electric and magnetic vectors respectively, ρ density of charge. More precisely $\rho = \frac{1}{4\pi} \nabla \cdot \mathbf{E}$ by definition.

Therefore the Maxwell electro-magnetic field in free space must have an undulatory structure, although, generally speaking, these undulations need not necessarily be simple harmonics either in time or in space. The real electro-magnetic field can be compared to very rough sea rather than with the artificially produced harmonic waves. Any possible state of this Universe of electro-magnetic waves must represent a solution of the Maxwell equations.

The only form of energy which can exist according to the Whirl theory is the energy of the electro-magnetic field, that is to say, the energy of the voluminal density $P \cdot P + S \cdot S$ (the proportionality constants are here omitted as immaterial for the present).^{*} The law of conservation of *this* energy need not be postulated, since, according to the well-known Poynting theorem, this conservation follows from the Maxwell equations.

As is well known the solution of the Maxwell equations within any limited space is determined by the e. m. field throughout the space at a certain moment of time ("initial conditions") and the e. m. field at the boundary of this space for all times ("boundary conditions").

The boundary conditions represent the mutual influence of the part within the space under consideration (possibly the whole known Universe) and the space outside the boundary.

If this space within the boundary forms a self-sufficient system, then the field at the boundary must be zero, and the whole physical history within the boundary will be determined by the initial conditions.

All the initial and *a fortiori* boundary conditions cannot be known, and unless we can supplement the Maxwell equations by certain principles, which could be equivalent to the initial and boundary conditions, the electro-magnetic history of the world, and especially of a limited part of the world which we can observe, will appear to us purely arbitrary.

Such principles, not only exist but are in fact included in the Maxwell Electrodynamics (which is wider than Maxwell equations).

From (4.1) $\nabla \times$ of either electric or magnetic vectors is zero if any of them remains constant in time and does not vary in space. Hence, in static fields $\nabla \times \nabla \times = 0$. On the other hand in free space, by definition $\rho = \frac{1}{4\pi} \nabla \cdot E = 0$. Hence in case of a static field in free space $\nabla \cdot \nabla = 0$, and consequently $\nabla = \text{const.}$ which actually means $\nabla \equiv 0$ for otherwise the field intensity would reach infinity, which is of course physically impossible. Hence the field must be constant throughout the space. This, however, is also impossible unless the field is zero, for in space free of charge the lines of force must be closed.

Thus Maxwell's electro-magnetic field in free space must always vary in space and time.

^{*} *Phil. Mag.*, XX, p. 435.

In the applications to the particular electro-magnetic structure which is manifested in the form of Light and Matter, these limitations are equivalent to the forces* between different systems of electro-magnetic waves. These forces follow the known laws of Mechanics, and their action among the multitudes of similar systems result in the equi-distribution of energy and momenta and in certain ways of transformation of systems which ensure their stability. The latter conservative tendency I called "minimum disturbance principle."†

Thus the limitations in the initial and boundary conditions of the Maxwell equations enables us to interpret the physical processes, when convenient, in terms of "ordinary" classical Mechanics, leaving out of account their electro-magnetic essence.

In the rough electro-magnetic sea of the Universe there can be distinguished stable component wave systems which I called "Electromagnetic Whirls" or simply "Whirls."

The Whirls, according to the solutions of the Maxwell equations which represent them, have an axial symmetry and a symmetry relatively to a central plane.⁸

The point of intersection between the central plane and the axis is called the "centre" of the Whirl.

The electro-magnetic waves of the Whirl rotate round the axis, forming a whole number of angular waves. The number of these waves (usually denoted by n) is called the "number of pairs of poles" of the Whirl, by analogy with the rotating magnetic fields in polyphase electric motors. In the radial direction the Whirl forms stationary waves with the wave-length depending upon the frequency and varying with the distance from the axis. In relation to the Whirls representing the elementary particles the wave-length of the radial stationary waves at a large distance from the axis tends to become practically equal to the corresponding light wave-length (c/v , where c is the speed of light and v the frequency). In the axial direction the Whirl forms an aperiodic field when it is stationary and periodic when it moves along the axis.

When the Whirl is stationary, the magnitude of the field represents an exponential function of the distance from the central plane. When, however, the Whirl moves as a whole, this function becomes exponentially-periodic with the wave-length satisfying the well-known de Broglie relationship

$$c_0 \cdot v_0 = c^2 \quad (4.2)$$

* *Phil. Mag.*, XX, pp. 673 and 675.

† *Phil. Mag.*, XX, pp. 673 and 675.

3 *Phil. Mag.*, XX, pp. 431 and further.

§ *Phil. Mag.*, XIX, pp. 935-943, and XX pp. 421-435, and pp. 441-446.

where c , is the speed of phase propagation of axial waves, v , the speed of motion of the Whirl.*

This relationship is here not an arbitrary postulate, as in the Quantum Mechanics, but a necessary condition of the physical possibility of Whirls in accordance with the Maxwell Electrodynamics.

Further, it has been found that the same Maxwell Electrodynamics requires the increase of frequencies in proportion, and the reduction of the axial distances in inverse proportion, to $\beta = \left(1 - \frac{v^2}{c^2}\right)^{-\frac{1}{2}}$. This of course agrees with the Einstein's Principle of Relativity.

These properties relate to any kind of Whirls. The type of Whirls which has special importance for the theory of elementary particles is the so-called "Compound Whirl".†

In further discussion we shall only deal with the Compound Whirls. Therefore for brevity we shall call them simply "Whirls."

The amplitude of the e. m. field intensity of this type of Whirl, apart from the above-mentioned exponential or exponentially-periodical variations with the distance from the central plane, varies with the distances from the centre of the Whirl and from the axis, in accordance with the rather complicated law which tends to approach asymptotically the inverse proportionality to the first degree of the distance from the centre and to square root of the distance from the axis.

It can be easily shown that such field distribution gives a *finite* total e. m. energy of the Whirl. Again on the basis of the Maxwell Electrodynamics, it has been found that the total energy of the Whirl is proportional to the frequency, while the angular momentum of the Whirl remains constant.§

Consequently the well-known Planck law represents one of the fundamental features of the Whirls. It has been found that the Planck constant $h = \frac{h}{2\pi}$ of the Whirl is equal to its double angular momentum.§

It has also been found that the Whirl possesses an inertial mass increasing with the speed in accordance with the well-known Einstein relationship. On the other hand, the total energy of the Whirl (which is, of course, its electro-magnetic energy) is equal to $m_0 c^2$, where m_0 is the stationary mass.||

(To be concluded).

* *Phil. Mag.*, XX, p. 428.

† *Phil. Mag.*, XX, p. 441.

§ *Phil. Mag.*, XX, pp. 438 and 447.

§ *Phil. Mag.*, XX, pp. 642-644.

|| *Phil. Mag.*, XX, pp. 456-458.

THE NATIONAL ACADEMY OF SCIENCES INDIA

BUSINESS MATTERS

1939

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ALLAHABAD

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PATRON

His Excellency Sir Maurice Hallett, K.C.S.I., C.I.E., I.C.S.,
The Governor of the United Provinces

HON. FELLOWS

Minister of Education,
The United Provinces

Pandit Madan Mohan Malaviya, LL.D.,
Formerly, Vice-Chancellor,
Benares Hindu University

BENEFACTOR

The Vice-Chancellor,
Allahabad University, Allahabad

His Exalted Highness The Nizam of Hyderabad (Deccan)

The Hon'ble Sir Shah Muhammad Sulaiman, Kt., M.A., LL.D., D. Sc., F.N.I., F.N.A.Sc.
Judge, Federal Court of India, New Delhi

ANNUAL MEETING

The Annual Meeting of the National Academy of Sciences, India, was held in the Mayo Hall, Allahabad, at 3 p.m. on Saturday, the 13th January, 1940. His Excellency Sir Maurice Hallett, K.C.S.I., C.I.E., I.C.S., Governor of the United Provinces, and Patron of the Academy presided over the function. Dr. Shri Ranjan, M.Sc. (Cantab), D.Sc., F.A.Sc., F.N.A.Sc., one of the General Secretaries, read the Report for the year 1939.

Pandit Amaranatha Jha, M.A., F.R.S.L., the Chairman of the Reception Committee, read his welcome address. The Hon'ble Sir Shah Muhammad Sulaiman, Kt., M.A., LL.D., D.Sc., F.N.I., F.N.A.Sc., the President of the Academy, delivered his address. His Excellency Sir Maurice Hallett then made a speech.

Prof. Y. Bharadwaja, M.Sc., Ph.D. (Lond), F.I.S., (Lond), F.N.I., F.N.A.Sc., proposed a vote of thanks to His Excellency the Patron of the Academy.

SECRETARIES' REPORT

PRESENTED AT THE ANNUAL MEETING OF THE NATIONAL ACADEMY OF SCIENCES,
INDIA, ON JANUARY 13, 1940.

BY SHRI RANJAN, M.Sc. (CANTAB.), D.Sc. (STATE-FRANCE), F.A.Sc.

We have the honour to submit the following report on the working of the Academy during the period beginning from the 1st January 1939 and ending with the 31st December 1939.

The Eighth Ordinary Annual Meeting of the Academy was held on Saturday, the 4th February 1939, at 3 p.m. in the Vizianagram Hall, Muir Central College Buildings, Allahabad. The Hon'ble Mr. Sampurnanand, Minister of Education, presided over the function. Rai Sahib Dr. P. L. Srivastava, one of the General Secretaries of the Academy, presented the annual report.

After Sir Shah Muhammad Sulaiman, Kt., M.A., LL.D., D.Sc., F.N.I., President of the Academy, had delivered his address, the Hon'ble Mr. Sampurnanand addressed the Academy, and gave away the Education Minister's Gold Medal to Dr. B. Sahni, D.Sc., Sc.D., F.G.S., F.R.S., F.N.I., Professor of Botany, Lucknow University, for his paper on "Materials for a monograph on Indian petrified palms."

It is a great pleasure to us to record here that, during the year under report, Sir Shah Muhammad Sulaiman, Kt., M.A., LL.D., D.Sc., F.N.I., was unanimously re-elected President of the National Academy of Sciences, India. The Academy has on its rolls 168 members who hail from every part of India. Of these 99 are elected Fellows, according to our constitution, on account of their special distinction in the domain of science. Eight Fellows have been elected during the period under report. Thanks to the scientific and philosophical activities of the Academy, it is maintaining its high reputation and steadily gaining popularity in and outside the country. Our Proceedings are on the exchange list of more than 170 Indian and foreign scientific journals. During the year under review, we published four issues of the Proceedings containing 25 original papers, the total number of such papers—Indian and foreign—communicated to the Academy being over 81. The papers published in the Proceedings have been widely appreciated and abstracted in all important Scientific Abstracts, and some reproduced *in toto* in other scientific journals. The Academy was also invited to represent itself at international congresses and other manifestations of international scientific activity such as the International Geological Congress, Great Britain, the International Congress of Genetics, Edinburgh, and the Two-Hundredth Anniversary of the Royal Swedish Academy of Sciences.

The financial position of the Academy, we are sorry to say, has not been as sound as one could desire. We are grateful to the Government of the United Provinces for the grant we have been receiving for the past several years. In the first year of its existence, the Academy of Sciences, U. P., received a grant of Rs. 4,000/- and it was in the hope that this grant would be made a recurring one that this Academy began to function. In subsequent years, however, owing to financial stringency, the Government has been giving only Rs. 2,000/- per annum although the Academy has meanwhile attained the status of an all-India body. We earnestly hope that the Government will be pleased to increase suitably the present grant and make it recurring. We are grateful to the Allahabad Municipal Board for a donation of Rs. 250/-. We trust that the Imperial Council of Agricultural Research, New Delhi, which granted us Rs. 500/- for the past three years successively, and His Exalted Highness the Nizam of Hyderabad who made a donation of Rs. 1,000/- last year and has graciously become our Benefactor, will be pleased to sanction similar amounts for the current year.

This year has unfortunately witnessed the beginning of a war against democracy and civilization, and in this grave moment of national calamity the National Academy of Sciences, India, has placed its resources at the disposal of the Government. Works on such subjects as the Power Supply in the United Provinces and India, the utilization of molasses in increasing the fertility of the soil and reclaiming waste lands, new conceptions of relativity, etc., are amongst the landmarks in the short but eventful life till now of this Academy. Our poor finances, however, have stood in the way of expanding the sphere of our activities and taking up new programmes of scientific enquiry. We are obliged to repeat in this connection what the Academy has, on previous occasions, stated before the authorities, Indian potentates, and the general public, that the paucity of funds does not permit us not merely to enlarge our Proceedings and organize a well-equipped Science Library, but to satisfy a need of fundamental nature, and that is, to have for the Academy a suitable building of its own. The need of such a building in which we can hold our meetings and house our library is urgently felt and the plan of the building is tentatively drawn up. We appeal to all those who appreciate what science has done and is doing for the advancement of knowledge and realize the value of science and scientific research for the well-being and uplift of the masses, to contribute liberally to the Building Fund of the Academy. All contributions, small or big, will be thankfully accepted.

In pursuance of the policy of the Academy to foster an atmosphere of research and invention all over the country, we have assembled our members and Fellows and eminent scientists from different parts of India and drawn up an adequate programme for our Annual Meeting of this year. It is a matter of special gratification and great encouragement to us that the Patron of the Academy, His Excellency the Governor

of the United Provinces, has been pleased to preside over this session. Sectional meetings in physical and biological sciences will be held under the chairmanship of Scientists, on the 2nd and 3rd day of this meeting; and we hope to continue this practice during our Annual Meetings in the future. We take this opportunity to submit that this Academy which justly claims for itself an all-India status, and has, among its members, scientists of international repute, should be consulted by the Government whenever a scheme of national importance arises; we respectfully assure the Government that all the expert advice or co-operation that the Academy is capable of, will be only too willingly offered.

The Education Minister's Gold Medal kindly offered this year by Dr. Panna Lall, C.I.E., I.C.S., D.Sc., Advisor to Governor, U. P., has been awarded to Prof. Mohd. Abdul Hamid Siddiqui, M.A., M.S., D.L.O., F.R.C.S., Professor of Anatomy, King George's Medical College, Lucknow, for his paper on "The Genito-Urinary System of the Indian Ground Squirrel (*Funambulus palmarum*)."

The Academy records with satisfaction the confirmation of the title of Rai Sahib on Dr. P. L. Srivastava, M.A., D.Phil. (Oxon.), who was a General Secretary of the Academy for the full period permissible under our constitution. The Academy congratulates Rai Sahib Dr. P. L. Srivastava on his well-earned distinction.

Dr. U. N. Chatterji, D.Phil, who served the National Academy of Sciences, India, as the Special Officer since 1937, was recently appointed a Lecturer in the Agra College, Agra, and the Academy records its appreciation of Dr. Chatterji's services.

We are glad to record that, during the year under review, the Academy secured the active, part-time co-operation of Dr. G. T. Kale from the International Institute of Agriculture, Rome, during his leave.

Finally, we wish to express our thanks to the Office-Bearers of the Academy and to the Members of its Council for their ungrudging help and active co-operation.

WELCOME ADDRESS

PANDIT AMARANATHA JHA, M.A., F.R.S.L.

CHAIRMAN OF THE RECEPTION COMMITTEE

At the Anniversary Meeting held on January 18, 1940

YOUR EXCELLENCY, MR. PRESIDENT, LADIES AND GENTLEMEN,

I extend to you a warm welcome to the Annual Meeting of the National Academy of Sciences, an institution that has had such distinguished presidents in the past as Professor M. N. Saha and Prof. B. Sahni (both of whom have also been General Presidents of the Indian Science Congress), and that is now so ably presided over by the Hon. Sir Shah Muhammad Sulaiman, who, having attained the highest eminence along the dusty purlieus of the law, is now returning to his first love, Mathematics, and is winning recognition as an original thinker and an expert in the use of symbols. Among its Fellows will be found most of the leading scientists in the country. Whatever may have been the apprehensions and doubts at the start, there can, I think, be no question now that the Academy amply justifies its existence as a clearing-house of ideas, as a convenient platform where scientific students and researchers can meet and discuss problems that are engaging their attention, and as link between administrators and captains of industry on the one hand and scientific investigators on the other. It publishes a journal, thereby ensuring prompt publication of research papers. It has a small but valuable library, fairly well equipped with the leading scientific journals both of this country and of other countries. The Academy fully merits all the support it can get from the State, the Universities, the industrialists, and above all the scientists themselves.

At a time like this when an educational administrator is constantly told that both research and teaching in the science laboratories are in danger of coming to a standstill because of the difficulties of obtaining supplies of apparatus and chemicals from Europe and of the impracticability of affording the high cost of material from America, may I suggest that you should consider the manner in which you can become independent of foreign supply? The want of chemicals and reagents is being acutely felt, and I am told that after about a year the situation will become very serious indeed. The reason for that is that we have depended on foreign chemicals and apparatus. The types of substances in which acute shortage is felt are certain pure inorganic chemicals and analytical reagents, organic solvents, dyestuff intermediate dyestuffs, medicinal chemicals and perfumery materials. In our Zoology Laboratory, animals and slides that used to be imported from Plymouth, Naples and Paris have not arrived this year. England is unable to supply articles of cast or moulded glass

like Kipp's apparatus and Desiccators. For the supply of other articles Priority Certificates, endorsed by the Government of India, have to be obtained. Japan and America can still supply some goods but at an absurdly high price. I am advised that the Indian Universities can step into the breach to a certain extent, provided they have funds. There is a vast possibility for others too, in the line of preparation of various products from ores available in this country; manufacture of alkali by large-scale electrolysis, manufacture of acids on a large scale; manufacture of basic organic materials like benzene. In the University of Allahabad we shall be willing, with only a small additional grant, to prepare a fairly large number of chemicals. Among Inorganic chemicals, potassium chloride, ammonium chloride and sulphate, potassium nitrate, copper sulphate, ferrous sulphide, sodium nitrate, ferric chloride, lead nitrate, silver nitrate, calcium chloride, magnesium sulphate, aluminium sulphate and zinc sulphate can be made here. A large scale distillation of coal tar for the recovery of benzene, phenol, cresols, and naphthalene is urgently required. With raw materials like benzene, toluene, phenol, and naphthalene available, it will be possible for us to prepare the dyestuff intermediates, and with these intermediates we can prepare such dyes as fluorescein, eosine, erythrosine, safranine, rhodamine, martius yellow, Naphthol yellow, aniline black, nigrosine, malachite green, methyl orange II, para red, Meldola's blue and magenta. The following medicinal chemicals can be prepared without much difficulty with the raw materials mentioned above: Salicylic acid, aspirin, chlorotone, salol, antifebrin, tannic acid, gallic acid, dermatol, phenacetin, phenolphthalein, lysol, thymol, iodoform and novocain. Our laboratory can also prepare citral, thymol, geranyl acetate, linalool, carvone, ethyl cinnamate, cineol, santalol and some other perfumery materials. Morphine and codeine from opium, strychnine from Nux vomica, vaccinine from Vasaka, Hollarhenine from Kurchi, Ephedrine from Ephedra and also Sida can be prepared here. Two assistants working in our Organic Chemistry Laboratory, with an initial grant of Rs. 4,000 for equipment and a recurring grant of Rs. 1,500 (in addition to the Assistants' salary) can without difficulty manufacture chemicals for laboratory and public consumption. I have a detailed scheme and I trust it will be possible for Government to sanction the erection of a small semi-largescale factory attached to our University. That will enable us to tide over our immediate difficulties and also help us to stand foreign competition even after the war.

The onlooker, they say, sees most of the game. And I, as an onlooker, may perhaps take a few minutes of your time, in stating some thoughts that suggest themselves to me. A nineteenth century poet said that each age is a dream that is dying, or one that is coming to birth. What is the dream of this age to be? To which star are we to hitch our waggon? What is to be our Eden? Are we to work for a society that will be governed by money? Or are we to conduct ourselves so that we shall earn the

esteem and regard of our fellow-beings? Or are we to have as our aim the long and healthy life, leaving behind us healthy children? In other words, are we to be mainly economic, or ethical, or scientific in our outlook? In order that we should lead a full life and starve no side of our nature, it is necessary that our ideal should be a composite one and that the principles of economics, ethics and science should be so finely adjusted as to form a harmonious whole. In such a view of our ideal, there is no room for arrogant claims by any one set of workers. The mango cannot spurn the melon, saying "Mine is the one fruit Allah made for man." It must be recognised, as Haldane says, that man lives in two worlds, the visible world which changes with time, and an invisible world whose constituents do not change. Life is made of matter and spirit, *Prakriti* and *Purusha*, and man ignores either the one or the other at his own peril. A purely materialistic view of life must be mistaken because it touches life at only a few points and leaves many gaps and gulfs that remain to be explored. It leaves untouched the very life of things. As Eddington says: "The materialist must presumably hold that his wife is a rather elaborate differential equation, but he is probably tactful enough not to obtrude this opinion in domestic life." The materialistic philosophy is responsible for science having been converted into pursuit of power. It has become also a serious source of difficulty and even disaster in the economic life of mankind. So great is the economic menace that a few years ago, in an article entitled "Unemployment and Hope," *Nature* suggested the scrapping of huge-scale factories, and the encouragement of small cottage industries or handicrafts, as also a combination of manufacturing with agricultural or garden industry. Science should clearly indicate what ideals it pursues. The rulers of States are blamed for their inability or unwillingness to adjust their economic organisation to the vast increase of productive power brought about by science. But is increased production needed or desirable? Science must give up its present position that it tries to acquire knowledge for its own sake. That is all very well for the worker sitting in his laboratory. What he cannot forget is the use to which this knowledge is likely to be put by the men who seek money or power or who have mere motiveless malignity. Knowledge is good, but wisdom is better. Both those who devote themselves wholly to theory and observation and those who are great inventors should remember in their pursuit of knowledge that the intellectual all-in-all who peeps and botanises over his mother's grave has killed some of the finer traits of human character. Knowledge is truly justified by its results. The aim of all endeavour should be welfare and happiness. Happiness is mainly a matter of the emotions. The scientist, by treating a rose and a tapeworm alike, by admitting no distinction between the face that launched a thousand ships and the dunghill, by studying them by the same methods and viewing them from the same angle, by deliberately stifling emotion and by a so-called disinterested love of knowledge, tends to come into conflict with ethics. The first considerable thinker

in Europe who expounded the materialist view was perhaps the poet Lucretius, in the first century B.C. An epicurean in his philosophy, he sought to explain 'the riddle of this painful earth.' He ends the first book of his poem "The Nature of Things" with the words:

"One thing after another will grow clear, and dark night will not rob you of the road and keep you from surveying the utmost ends of nature: in such wise things will light the torch for other things."

Unfortunately Lucretius suffered from fits of insanity and died by his own hands! The extreme scientist, in his claim for omniscience, condemns religion as a complicated fear, or a sublimated sex-instinct, or a combination of credulity and duplicity. But, fortunately for us, some of the more thoughtful of contemporary scientists, Jeans, Whitehouse and Eddington, for instance, have realised that there are more things in heaven and earth than are dreamt of in science. At the same time, recent work in physics and biology in discovering the unity of matter and energy, and the direction working in the process of evolution, has provided a basis for faith in an eternal Sovereign Energy or Force or Being, the main article of all religious faiths. Lord Morley, an agnostic who toyed for a while with Positivism, said once that the next great task of science is to create religion for humanity. May we not hope that the words of Lord Bacon will be constantly remembered by the scientists, that science should be "a rich storehouse for the glory of the Creator and the relief of man's estate?" The arche-type of the seeker after knowledge and power, divorced from morality, had dreamed of a world of profit and delight, of power, of honour, of omnipotence, had hoped to command all things that move between the quiet poles, and yet ended his days, saying that he wished he had never seen Wertheim, never read book. The purely atheistic attitude and consequent materialism of the later years of the nineteenth century are fortunately things of the past. There is to be seen a more reverent, one might almost say religious outlook in contemporary writings by the more thoughtful scientists, and it indeed seems to a layman that recent discoveries and researches suggest, in the words of Sir J. A. Thomson, that what science shows is that we cannot "make sense" of the Universe and our place in it unless we believe in the reality of Purpose—of Divine Design that has counted throughout the past and will continue to count in the future. We are told by a scholar like Professor Crowther, an authority on Molecular Physics, that modern science, face to face with the mystery of the act of Creation, can only repeat the words of the Bible, "And God said, let there be light: and there was light." Professor Lloyd Morgan finds in evolution one great scheme from first to last suggesting Mind or Spirit as Creative and Directive of all novelty and all recurrence. Dr. MacBride, a leading Zoologist, thinks that the directing, regulating power of life did not originate in chance encounters of atoms, and asks "He that planted the ear shall He not hear?" Sir William Bragg, pointing out what

Physical Science has found out, says that matter, electricity, energy, each in turn has been fashioned in the same strange way. All this is satisfactory. It is well that science should point to the enquirer that the real quest is the respectful knowledge of the Creator and Director of the Universe. But it must be remembered, too, that the State has a grave duty towards Science. The scientist can only work if he is paid—unless he has independent means of his own. The industrialist, the private employer, or the State pays him to work. As Professor Julian Huxley says, the amount of money spent will determine the emphasis on different branches of science. "Science is a resultant of a number of forces: first of all, the natural disinterested curiosity of certain men; secondly, the desire of others to get things done and acquire control over nature; thirdly, the general temper of the time; fourthly, the amount of money spent by those who control the purse-strings; then the nature of the general economic system." Science is thus a social function. Almost all our business now is connected with science. The developments of electrical engineering, or of the chemical industries, or of the means of transport, or of means of inter-communication, or of the use of rubber, alloy steels, cellulose—all of such moment to us in our personal and business affairs—we owe to science. To it too we owe our knowledge of the hydrogenation of petrol, the cure of diabetes, anæsthetics, plant-breeding and so on.

There can be no limit to the possibilities of scientific achievement, especially if we do not use science in the narrow sense in which it is sometimes used. Among the abstract sciences are such branches of study as metaphysics, logic, statistics, mathematics. Among the applied sciences may be included economics, education, medicine, engineering, metallurgy, agriculture. Sociology, psychology, æsthetics, anthropology also claim to be sciences. Thomson's "Outline of Science" has a chapter even on "Psychic Science." This is all to the good. The larger the sphere traversed by science, the more varied the topics examined with precision by the scientist, the more distant and complicated the objects analysed by the methods of science, the greater will be our sense of marvel, our feeling of reverence and awe, our discovery of some new beauty, some wisdom beyond the dream of the wise.

ADDRESS OF THE PRESIDENT

The Genesis of Relativity

THE HON'BLE SIR SHAH SULAIMAN, KT, M.A.
LL.D., D.Sc., F.N.I., F.N.A.Sc.

At the Anniversary Meeting Held on January 31, 1940

YOUR EXCELLENCY, FELLOWS AND MEMBERS OF THE ACADEMY, LADIES AND GENTLEMEN,

Relativity undoubtedly is one of the greatest theories of the 20th Century. This great Theory has almost dethroned Newtonian Mechanics and replaced its concepts of space and time. But the fundamental postulates on which the whole Theory is founded are extraordinary and on a first impression even astounding. It is a common belief that there are just a few postulates which suffice. But when the logical order in which the Theory has developed is examined step by step, it becomes only too apparent that there are a very large number of postulates forming its main planks, only a few of which can be deduced from some of the others. If any of these postulates proves to be false, the whole lofty structure may crack and collapse. The postulates of the Special Theory remain concealed behind the supposed null effect of Michelson's experiment and Lorentz's transformation formulæ, and those of the General Theory behind the intricate and complex application of the Tensor Calculus. The reputation of the Theory rests on the old claim that its mathematical results had been verified by actual observations. With the progress of Science, however, there is greater and greater accuracy in making measurements. And the latest observations undoubtedly cast doubts on the proclaimed confirmations. It is accordingly interesting to re-examine the very premises on which the Theory is founded and bring out clearly the assumptions underlying it. Only then can we test the soundness of the philosophy that is sought to be evolved out of it.

MICHELSON-MORLEY EXPERIMENT

In 1881 Michelson devised an interferometer and with it performed his famous experiment, which was repeated jointly with Morley in 1887. The principle of the experiment can be stated in a simple way. Light proceeding from a terrestrial source S falls on a glass plate G, which is slightly silvered so that one half of the light passes through to the mirror M_1 and the other half is reflected

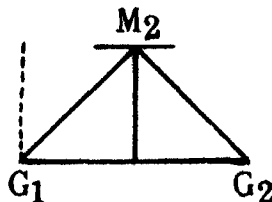
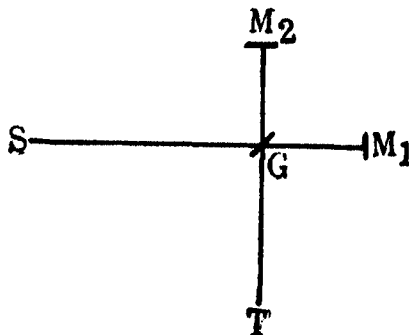
to an equidistant mirror M_2 . Both these are reflected back to the glass plate G . As both pencils have travelled the same distance they recombine in the same phase of vibration in the telescope T . ($GM_1 = GM_2 = d$)

In a direction parallel to the motion of the Earth, the mirror M_1 approaches to or recedes from the light. The relative velocity is therefore $c \pm v$, where v is the velocity of the Earth and c that of light. Time taken by light in the direction of the Earth's motion is

$$t_1 = \frac{d}{c-v} + \frac{d}{c+v}$$

In the direction perpendicular to the Earth's motion, the light traverses two sides of a triangle. The time

taken in this journey is $t_2 = \frac{2d}{\sqrt{c^2 - v^2}}$



The difference between the two times should be

$$t_1 - t_2 = \frac{2d}{c} \left(\frac{1}{1 - \frac{v^2}{c^2}} - \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} \right) = \frac{d}{c} \cdot \frac{v^2}{c^2} \text{ nearly, neglecting } \frac{v^3}{c^3}.$$

The difference in the times should introduce a difference in the phases of the two pencils causing a shift of the interference fringes. The displacements observed by Michelson and Morely even when the apparatus was rotated were not more than 25 per cent. In the report as published in the Philosophical Magazine, (5) 24, 449 (1887), their conclusion was "the observed relative motion of the Earth and ether did not exceed one-fourth of the Earth's orbital velocity."

FITZGERALD-LORENTZ CONTRACTION

Fitzgerald and Lorentz suggested that every material body which has the velocity v in the ether contracts in the direction of its motion by the fraction $\sqrt{1 - \frac{v^2}{c^2}}$, which would then make $t_1 = t_2$, explaining the null effect.

The Special Theory

The Special Theory of Relativity was invented by Dr. Albert Einstein to explain this null effect. A little reflection will show that there are other possibilities of explaining the result. To exclude them, he had at the very outset to assume, either expressly or by necessary implication, the following postulates:—

POSTULATE NO. I.—*Experimentally the null effect is not only approximately true, but is exactly true.*

There might in fact have been a displacement of the interference fringes, though not as large as was expected. Many later experiments were performed which were supposed to confirm the null effect. But the most elaborate experiment is that of D.C. Miller, who [Review of Modern Physics, July, 1933, Vol. 5, pages 204–242] found displacements varying from 4 to 15 per cent. His definite conclusion is that there is no null effect, but there is in fact an ether drift of about 10 km/sec.

POSTULATE NO. II.—*It is impossible to detect the absolute motion of the Earth by any experiment performed on the Earth.*

When rain drops fall vertically, a person standing motionless would see them fall vertically over his head; but if he were to run along, he would notice the drops falling in an inclined direction towards him, because the two velocities are compounded. In the same way, the velocity of the light coming from distant stars has to be compounded with the velocity of the Earth moving in its orbit. And so an astronomer when observing such stars has to point his telescope forward or backward according as the Earth is moving towards or away from these stars, irrespective of their velocities. In this way a change in the absolute motion of the Earth is detected by experiments performed on the Earth when light comes from outside.

POSTULATE NO. III.—*The velocity of light is wholly independent of the speed of the source of light.*

We know that a stone thrown vertically upwards falls on the same spot from where it was thrown up irrespective of the motion of the Earth, because it also possesses that motion. Similarly, a ball thrown from the hands of a passenger sitting inside a train would take the same time to travel a given distance, no matter whether it is thrown parallel or perpendicular to the direction of the train. The obvious reason is that the stone already possesses the velocity of the Earth and the ball that of the train. In the same way if the velocity of light from a terrestrial source were affected by the motion of the source, the motion Earth might not be detected.

POSTULATE NO. IV.—*The velocity of light is wholly independent of the direction of the motion of the source.*

This means that the velocity of light emitted from a source neither partakes of the component of the velocity of the source in the direction in which it is received, nor of the transverse component perpendicular to that path.

As regards de Sitter's test of binary stars, it cannot be regarded as conclusive because the orbits may have eccentricities.

POSTULATE No. V.—*The Law of Reflection is the same whether the reflecting surface is stationary or is moving towards the coming light.*

In one position the mirror M_1 was approaching towards the coming light

POSTULATE No. VI.—*The Law of reflection is the same whether the reflecting surface is moving away from the light or whether it is stationary*

In that position the plate G was receding from the reflected light.

POSTULATE No. VII.—*The Law of reflection is the same whether the reflecting surface is slipping towards the coming grazing light or whether it is stationary.*

The mirror M_2 could be slipping towards the light

POSTULATE No. VIII.—*The Law of reflection is the same whether the reflecting surface is slipping away from the grazing light or whether it is stationary.*

The experiments performed by Majorana have not been regarded by physicists as conclusive because the error of observation was large. Even after liberally allowing for such errors he himself found an excess of 5% in the displacement of fringes.

POSTULATE No. IX.—*The Law of Refraction is the same whether the refracting medium is approaching the coming light or whether it is stationary.*

The plate G in one position was approaching the light from the source.

POSTULATE No. X.—*The Law of refraction is the same whether the refracting medium is receding from the coming light or whether it is stationary.*

In another position the plate G would be receding from the light.

POSTULATE No. XI.—*The Law of Refraction is the same whether the refracting medium is moving perpendicular to the path of light away from the normal to itself or whether it is stationary.*

The motion of the refracting plate G in one position would be perpendicular to the light from mirror M_2 and away from its own normal

POSTULATE No. XII.—*The Law of refraction is the same whether the refracting medium is moving perpendicular to the path of light and towards the normal to it or whether it is stationary.*

In another position the motion would be towards the normal.

POSTULATE No. XIII.—*The time taken by light to reach an approaching surface is exactly the same as that taken by light to overtake a receding surface, when both the surfaces were equidistant initially.*

Michelson-Morley Experiment at best only showed the result of double journey, to and fro, of light, and not of each single journey of it. But Einstein assumed that the times in the two parts of the whole journey were equal

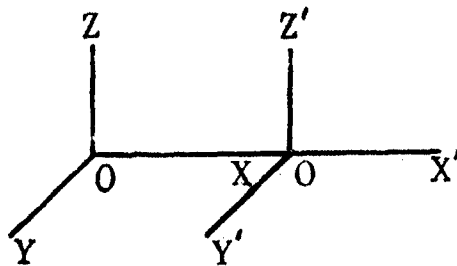
He defined Time by the extraordinary assumption that the time taken by light to go from one object A to another object B is the same as the time taken to go from the object B to the object A, no matter in what direction and with what velocity the two bodies A and B may be moving. In the rotation of the Galactic System, the Sun and adjacent stars may be moving at about 200 miles per second, and there are stars from which light would take several years to come to the Sun. According to Relativity if the Sun and such a star are moving round in the same direction at this tremendous speed, light from the Sun would take the same time to go to the star as light would take to come from the star to the Sun, which is tantamount to ignoring their respective velocities altogether.

POSTULATE NO. XIV.—*The optical theory of light is such that an experiment designed to measure the phase difference can be interpreted as one for measuring the constancy of the velocity of light.*

The experiment did not actually measure the velocity of light, but only attempted to observe a displacement of the interference fringes

With these postulates, Einstein put to himself the question: What should be the mathematical basis for a new Theory to explain the null effect? He propounded the answer by an abandonment of the classical concepts of time, space, and the motion.

POSTULATE NO. XV.—*The optical laws are invariant in form under any transformation from one system to another in relative uniform rectilinear motion.*



The formula in classical physics of the propagation of light according to fixed axes (ox, oy, oz) is

$$dx^2 + dy^2 + dz^2 - c^2 dt^2 = 0$$

If ($o'x', o'y', o'z'$) be another set of axes of moving uniformly with velocity v along ox then $dx' = dx - vdt$, the other values remaining unaltered. Accordingly,

$$dx'^2 + dy'^2 + dz'^2 - c^2 dt'^2 = (dx^2 + dy^2 + dz^2 - c^2 dt^2) + (v^2 dt^2 - 2v dx dt)$$

Now, if v is not zero, the following two expressions cannot mathematically be equal $dx^2 + dy^2 + dz^2 - c^2 dt^2$ and $dx'^2 + dy'^2 + dz'^2 - c'^2 dt'^2$ unless $c^2 dt'^2$ also changes with x' , which means that either c or t must change.

In the classical mechanics time t is absolute and remains the same for all bodies, while the velocity of light varies from one system to another when in relative motion. Einstein, however, assumed that the relative velocity of light in vacuum does not change at all, but time changes.

POSTULATE NO. XVI.—*That it is not only the average value of the relative velocity of light in a to and fro journey in vacuum that is constant, but that the relative velocity of light even in a single journey is absolutely constant.*

This means that light either moving towards an electron travelling say with two-thirds of the velocity of light or moving away from such an electron or overtaking it is supposed to possess exactly the same relative velocity. As Eddington has himself said, "a beta particle shot off from Radium can move at more than 120,000 miles per second, but the speed of light relative to such a moving electron is still 186,000 miles per second." Although light travels at the known and finite velocity of 186,000 miles per second, yet in Relativity its velocity relative to a moving body, howsoever fast it may be moving and whether light may be overtaking it or receding away from it, is still the same 186,000 miles per second. This amounts to attributing properties of infinity to a finite velocity, as no velocity howsoever great when added to it or subtracted from it can ever make any difference.

Had the velocity of light relative to the Earth been always the same, no matter in what direction the Earth be moving, then strictly speaking there ought to have been no aberration at all. If the velocity of light were absolute, there should be no question of its being compounded with the velocity of the Earth.

POSTULATE NO. XVII.—*Absolute Time does not exist, but time depends on the velocity of moving observer.*

As the velocity of light was assumed to be absolutely constant, the absoluteness of time had to be abandoned. In this way he made

$$ds^2 = dx^2 + dy^2 + dz^2 - c^2 dt^2 = dx'^2 + dy'^2 + dz'^2 - c'^2 dt'^2$$

Relativity correlates the time at different places by moving a clock from one to the other with infinitesimal velocity—a contradiction in terms. Two persons moving with different velocities keep altogether different times. Every body keeps his own separate time without any thing common to compare with, and his time depends on his own velocity. Thus as Max Born has admitted, "If A and B were twin brothers, then B must be younger when he returned from a voyage than A. This is a strange deduction which can, however, be eliminated by no artificial quibbling. We must put up with this." The reason is that Time moved more slowly with the one who travelled. But this

is not all. As everything in Relativity is relative, so the first brother might be taken to have remained stationary and the second brother as having performed the double journey and become younger. Thus at one and the same time the first is younger than the second, and the second is younger than the first.

Faced with this self-contradiction, the relativist uses the stock argument that this inexplicable result is due to the fact that there is no common standard of time for measurement, and that suggests there must be different amounts of time between the two meetings, one for the elder and the other for the younger. But obviously there is a fatal objection to this supposed explanation. Even in the Space-Time continuum of four dimensions, Space has three co-ordinates (x, y, z) while Time has only one $\sqrt{-1} t$. It is, therefore, patent that there can be several spacial routes from one event to another, while only one temporal route is possible. The conception of the two different amounts of time between the same two events is an impossibility.

POSTULATE No XVIII.—*Absolute simultaneity is meaningless.*

One has to agree with Einstein that as light messages take time to come from distant objects, it is impossible to be exactly certain of the simultaneity of the events which have occurred at those places. But even though the exact simultaneity of two events as observed may, in practice, be doubtful within certain limits, and two different observers moving with different velocities would not be able to agree as to the simultaneity of two events, it is not possible to deny that two natural events may in reality be simultaneous, and co-existent in the absolute sense. For instance, it may not be possible to ascertain the exact positions which the Sun and the Earth occupy at any given instant, yet it cannot also be denied that they must, at one and the same time, necessarily occupy some particular positions, even though not specified, as they undoubtedly exist together. Nor can any one dispute the simultaneous existence of living organisms. Undeniable time-succession of events demonstrates the independence of time.

The uncertainty, if any, is purely subjective and should not be confused with objective uncertainty. The existence of natural phenomena is not dependent on the observation of Man. They had existed for millions and millions of years long before Man was born. Time was running long before Man came into existence. Theoretical philosophy should not be founded exclusively on the practicability of exact measurements. The human mind is transcendental and should be able to comprehend the structure of Nature without any actual visual perception.

POSTULATE No XIX.—*Absolute Space is meaningless.*

The denial of the absoluteness of Time necessitated the denial of the absoluteness of Space also. The classical conception was one of absolute Space and absolute Time. Time and Space were considered as separate, distinct and independent

units. Space was determined completely by three dimensions, *viz.*, length, breadth and height, but Time was an independent variable and could, by no stretch of the imagination, be regarded as a dimension of Space. Space was the emptiness in which material bodies could float about, and could be defined as something which was either actually occupied by matter, or was at any rate a void, capable of being so occupied. Time had a continuous flow, was eternal, and existed from eternity as a separate entity. Both Space and Time were existent by themselves independently alike of the mind which apprehended them and the objects with which they were associated.

Einstein has revolutionised the old idea and announced that Space and Time are inter-dependent and that Time can be regarded as the fourth dimension of a new Space-Time continuum. But to combine it with Space he has given to Time an imaginary and unreal unit as it is not commensurable with Space. He has welded Time and Space together so as to form a new hyper-Space of four dimensions instead of the familiar three.

There is a partial truth in Einstein's hypothesis of the interdependence of Time and Space. In practical measurements it may be difficult to separate Space and Time, as the measurement of Space by going from one point to another necessarily involves a certain lapse of time showing their mutual inter-relation. But Time has two distinct attributes by which we can perceive it. First, it is measured by a change of position in space with change of time; for example a motor car goes from one place to another in a definite time. Secondly, Time is measured by a change of state, particularly of a living organism, for instance after a number of years a child becomes a grown-up lad. Regarding the child as an entity, this change is not manifested by his altered position in Space, but by his changed condition, namely the transition from childhood to youth, involving the development of his knowledge and intelligence. A four dimensional continuum can artificially describe motion and the inter-relation of Time and Space, but not the growth of a child's intelligence with years. It is this second ignored attribute of Time which really demonstrates that Time is absolute and independent of Space. No matter how much one may deny it, human consciousness of time is very real.

POSTULATE NO. XX.—*Absolute Motion is meaningless.*

If absolute Space and absolute Time do not exist, then necessarily absolute Motion cannot exist. The old conception of absolute motion which Relativity denies was theoretical and not experimental. In actual practice it is impossible to find the absolute motion of a body as the observer must himself be ignorant of his own absolute motion. This is all very well, but to deny the existence of absolute motion altogether is quite another thing, and is certainly wrong. So long as one has only two objects to compare, it matters little mathematically which of the two is assumed to be at rest and which assumed to be moving relatively to it. For instance if we

compare the Earth with the starry Heavens, the rotation of the Earth on its axis once a day, and the revolution of the entire Heavens, round the Earth once a day may be mathematically equivalent. All the same it is impossible to accept the Relativity interpretation as stated by Bertrand Russell. "In the modern theory the question between Copernicus and his predecessors is merely one of convenience; all motion is relative and there is no difference between the two statements: the earth rotates once a day and the heavens revolve round the earth once a day. The two mean exactly the same thing". If two motorists coming from opposite directions stop their cars to avoid a collision, they do not fling away the earth in opposite directions at the same time. Or when a boy spins a top, he knows that he has set the top in motion, and would not agree with the Relativist if told that he might just as well have set the whole Universe revolving round in the opposite direction.

The denial of absolute motion cannot be carried too far, and its falsity becomes at once exposed if the simultaneous rotations of three bodies or more are considered. If an electric fan is revolving in a room, one can say from a purely mathematical point of view that as its motion is only relative, it is not necessarily the fan that is revolving in the room, but that the room itself may be revolving round the fan. But if there be three or more electric fans revolving in the room at the same time, it would be impossible to treat the motion as a rotation of the room itself round all the electric fans simultaneously. The simultaneous observation of a number of angular motions demonstrates unmistakably the absoluteness of such motions.

POSTULATE NO XXI -- *Only Relative Motion is real.*

After denying the absoluteness of single motion, the only alternative left was an assertion of absolute relative motion. Einstein has rejected absolute velocities on the ground that it is impossible to measure them, and assumes that we can measure relative velocities, independently of the absolute velocities. But the fact is that just as it is impossible to measure exactly the absolute motion of a body, so it is equally impossible to measure exactly the relative motion of two bodies. There is really no other means of measuring relative velocity than the employment of a messenger moving to and fro with a finite velocity. Newton's Mechanics was designed for a superman, who could observe absolute distances, absolute time and absolute motion instantaneously and could therefore measure the relative velocity exactly. But a human observer has to employ a messenger travelling to and fro and is not aware of his own absolute motion, and therefore cannot exactly measure even the relative velocity of a distant object as compared to himself. The value obtained by him would vary with the method of measurement selected. If the absoluteness of Space and Time be rejected, then absolute relative velocity becomes an uncertain quantity. Indeed it is just as impossible to measure exactly the actual relative velocity, *i.e.*, the difference between the two absolute velocities, as to measure the exact absolute velocity themselves. Even Doppler effect cannot really give the

exact relative velocity, in spite of the Relativity assumption to the contrary, as frequency should depend on whether the source or the observer is moving.

POSTULATE NO. XXII.—*The postulate of invariance is not only true for an infinitesimally small region but holds good for light even in a larger region.*

So that $x^2 + y^2 + z^2 - c^2 t^2 = x'^2 + y'^2 + z'^2 - c^2 t'^2$

Keeping $y = y^1$ and $z = z^1$, the following Lorentz transformation formulæ

$$x = \frac{x^1 - vt^1}{\sqrt{1 - \frac{v^2}{c^2}}}, \quad y = y^1, \quad z = z^1,$$

$$t = \frac{t^1 - \frac{vx^1}{c^2}}{\sqrt{1 - \frac{v^2}{c^2}}}$$

happen as a particular case to satisfy the above equation. It is then assumed conversely that the single equation

$$x^2 - c^2 t^2 = x'^2 - c^2 t'^2$$

necessarily leads to those transformation formulæ. But obviously one single equation cannot yield values of both x and t in terms of x^1 and t^1 separately, even quite apart from the undeniable difficulty that x and ict are in themselves interchangeable.

Then a fictitious geometrical meaning is given to these formulæ by a supposed artificial rotation of the spatial axes round an imaginary axis of time.

Analogous transformation formulæ are obtained for :

- (a) relative velocities, and
- (b) relative accelerations.

Previously Space which was equivalent to volume was fixed by length, breadth and thickness. But in Relativity length has no definite meaning ; it depends on the velocity of the body, and contracts in the direction of motion, but not transversely.

Even though the contraction is not physical but perceptual, it involves an obvious paradox of a rotating ring. Its circumference would contract because the motion is along its length, but the radii which move transversely will not contract. To circumvent this absurdity, a further assumption is made that the particle density of the ring alters. But the question of density with regard to a theoretical circumference is beside the point. In any case change of density cannot prevent the enlargement of the circumference while the radii remain unaltered. Even when correction is made for acceleration and density, the anomaly is removed only approximately and not exactly in accordance with Lorentz' transformations. So in principle the objection is fatal.

If a right-angled triangle be moving with velocity-parallel to its base, then its sides which originally were a , b and $\sqrt{a^2 + b^2}$ become a , $b\sqrt{1 - \frac{v^2}{c^2}}$, and $\sqrt{a^2 + b^2}\sqrt{1 - \frac{v^2 \cos^2 \alpha}{c^2}}$, where α is the angle between the base and the hypotenuse,

So that when α approaches $\frac{\pi}{2}$ and v increases, the hypotenuse will become greater than the sum of the other two sides — a serious objection.

The formula for relative velocity is
$$\frac{v_1 - v_2}{1 - \frac{v_1 v_2}{c^2}}$$

Take a velocity slightly less than c , say $(c - e)$ where e is very small. The relative velocity of light to this is
$$\frac{c - (c - e)}{1 - \frac{c(c - e)}{c^2}} = c$$

Hence when e approaches zero, so that the other velocity approaches to that of light and almost equals it, the relative velocity is still that of light! Incomprehensibility could hardly go further

On the other hand, "If the fundamental velocity is exactly 300,000 km/sec, and two points move in the same direction with speeds of 300,001 and 299,000 km/sec the speed of one relative to the other is 180,000,000,000 km/sec." (Eddington). As the difference between the two speeds approaches zero, and they both have the same velocity, their relative velocity tends to infinity! A mere assertion that velocity greater than light is impossible is not an explanation but another postulate.

POSTULATE NO. XXIII.—*The momentum is not the mass multiplied by change of position dx per lapse of interval dt $\left[= m \frac{dx}{dt} \right]$, but is $m \frac{dx}{ds}$.*

The principle of the conservation of momentum is that the product of the mass of a body and its velocity remains constant, if there is no external force acting. This conservation cannot hold in Relativity. Einstein has therefore, in order to deduce a principle of conservation, modified the definition of momentum itself

POSTULATE NO. XXIV.—*The mass of a body is not m but $M = m \frac{dt}{ds}$.*

In classical mechanics the mass m remained constant even if the velocity changed. But in relativity the so-called electromagnetic mass M is no longer an invariant for a particle, but depends on its motion relative to the different observers' different space-time. $M = \frac{m}{\sqrt{1 - \frac{v^2}{c^2}}}$, i.e. mass changes with the velocity. But the velocity is

not absolute; it is relative. Hence mass also has no definite meaning; its value is merely relative to an observer.

And yet Relativity cannot altogether get rid of the inertial mass, which is the proper mass of a body. This so-called 'rest mass' of a particle, where $v=0$, is real. The conception of mass being dependent upon velocity is accordingly inexact. As in classical mechanics, a body assumed to be at rest must have an invariable rest mass. We thus come back to an intrinsic rest mass dependent on the inertia of the body, and quite independent of the velocity which it may possess "a constant number, the invariant mass denoting its absolute inertial properties and remaining unaltered throughout the vicissitudes of its history." (Eddington)

POSTULATE NO. XXV.—*The Energy is the relative mass multiplied by the square of the velocity of light.* $E = \frac{mc^2}{\sqrt{1 - \frac{v^2}{c^2}}}$

If the conservation of mass were represented by $\sum \frac{m}{\sqrt{1 - \frac{v^2}{c^2}}}$, then the classical

law of conservation of energy $\Sigma(\frac{1}{2}mv^2)$ has also to be abandoned. Einstein has therefore had to frame a new definition of Energy. But still more serious difficulties arise.

When radiant heat which is electromagnetic mass (energy) falls on matter, its temperature rises, the increased energy of motion of the molecules causes an increase of electromagnetic mass (M) and therefore also the rest mass (m), since it is equal to M for a body at rest. But the electro-magnetic waves have no rest mass, and so the *increase of intrinsic rest mass is created out of nothing*. The only explanation which relativity can offer is that "invariant mass is not conserved in general The invariant mass of a (body) is not exactly equal to the sum of the invariant masses of its constituents." (Eddington.) This is contrary to what was assumed before.

If a positron and an electron coalesce and annul one another, their electromagnetic mass can pass into electro-magnetic waves, but the rest mass would have to *disappear into nothing* and would have to be completely annihilated.

If helium were formed out of hydrogen, part of the invariant mass m will have to be *annihilated*, and a corresponding proportion of the relative mass M will be liberated as radiant energy.

POSTULATE NO. XXVI.—*The density of a body is dependent on its velocity.*

As the volume of a body varying with its dimension in the direction of motion is not absolute, the particle density necessarily becomes a relative term.

$$\rho' = \rho \left(1 - \frac{v^2}{c^2} \right)$$

POSTULATE NO. XXVII.—*The action is not ($\frac{1}{2}mv^2 dt$) but $mds = Mdt$.*

This is a necessary result of all the changed definitions of mass, time and energy.

POSTULATE NO. XXVIII.—*Absolute temperature of a body has no significance, the relative temperature is, $T' = \frac{T}{\sqrt{1 - \frac{v^2}{c^2}}}$*

As both Entropy and temperature cannot be invariant in Relativity, Einstein assumed that although Entropy is invariant, temperature is not so.

The General Theory

The method of developing the General Theory as adopted by Sir Arthur Eddington is here taken as the standard

POSTULATE NO. XXIX.—*The interval between two neighbouring events is represented by a quadratic function of the differences of their co-ordinates.*

$$ds^2 = \sum g_{\mu\nu} dx_\mu dx_\nu$$

and not a general quartic function of the differentials. The more general form is assumed to be inadmissible.

Although the first derivatives of g 's can by transformation of co-ordinates be made to vanish at any selected point, the second derivatives do not necessarily do so. Thus even in a small region the g 's can be treated as constant only approximately.

POSTULATE NO. XXX.—*There is a small region of the world throughout which the g 's are constant as compared to the differentials.*

In an infinitesimal region the g 's can be treated as constant only if they do not themselves involve differentials.

POSTULATE NO. XXXI.—*The real interval can be represented by a term admitting imaginary co-efficients*

Without this assumption the reduction to the sum of four squares of complete differentials can not be always possible. The quadratic function is then expressed as an exact sum of four squares.

$$ds^2 = dy_1^2 + dy_2^2 + dy_3^2 + dy_4^2$$

POSTULATE NO. XXXII.—*Of the four co-ordinates of a real event, (1) three are real standing for spatial co-ordinates, and (2) one is unreal standing for temporal co-ordinate.*

These two assumptions are made in order to exclude the other possibilities of the real or the unreal character of each of the four co-ordinates. Theoretically we can have not only time-like but also space-like structures. If four co-ordinates are

to be chosen, then instead of a 3+1 dimensional world, we can have 2+2, or 1+3, or 0+4 or 4+0 dimensional world, leading to other absurdities.

Einstein has assumed $ds^2 = c^2 dt^2 - dx^2 - dy^2 - dz^2$

POSTULATE NO. XXXIII.—*The track of light in a small region is a geodesic, with $ds=0$.*

To condition $ds=0$ for light is a necessary result of the postulates of the Special Theory.

POSTULATE NO XXXIV.—*What is true in an infinitely small region, is equally true for a large region, and $ds=0$ holds true for light velocity all along the track even in a large region.*

If the reduction into a sum of four squares was only approximate and not absolutely exact, then the same result cannot be presumed for a large region.

POSTULATE NO. XXXV.—*The path of a freely moving particle in a gravitational field is always a geodesic.*

The differential equations of the tracks in a non-gravitational field are written as $\frac{d^2 x}{ds^2} = 0$, etc., which on integration give $\int ds$ is stationary. Then the generalisation is made that the particle moves in such a way that

$\int ds$ is stationary for all arbitrary small variations of the track. In mathematical language.

$$\frac{d^2 x_\alpha}{ds^2} + \left\{ \mu\nu, \alpha \right\} \frac{dx_\mu}{ds} \frac{dx_\nu}{ds} = 0, (\alpha=1,2,3,4).$$

POSTULATE NO. XXXVI.—*The most general form of ds^2 in a gravitational field contains co-efficients which are purely functions of r .*

When expressed in polar co-ordinates it takes the form—

$$ds^2 = U_{(r)} dr^2 + V_{(r)} (r^2 d\theta^2 + r^2 \sin^2 \theta d\phi^2) + W_{(r)} dt^2$$

where r may represent the distance from the source.

POSTULATE NO. XXXVII.—*The law of gravitation in empty space is*

$$G_{\mu\nu} = - \frac{d}{dx_\alpha} \left\{ \mu\nu, \alpha \right\} + \left\{ \mu\alpha, \beta \right\} \left\{ \nu\beta, \alpha \right\} + \frac{d}{dx_\mu dx_\nu} \log \sqrt{-g}$$

$$\left\{ \mu\nu, \alpha \right\} \frac{d}{dx_\alpha} \log \sqrt{-g} = 0$$

This is quite an arbitrary assumption.

POSTULATE NO. XXXVIII.—*By transformation although ds^2 remains invariant, the co-efficients of $d\theta^2$ and $d\phi^2$ are unity.*

If we transform the expression by substituting r^2 for $r^2 V(r)$, and reduce the second co-efficient to unity, the significance of r as the distance from the source would disappear. On the other hand if the significance is retained then an assumption must be made that the co-efficient is unity.

The first and the last co-efficients are expressed as approximations of exponentials e^λ and e^ν , and not in the more general form $1 + \sum \frac{A_n}{r^n}$.

POSTULATE No. XXXIX — *A particular solution of $G_{\mu\nu} = 0$ obtained by Schwarzschild governs the form of planetary orbits.*

$$ds^2 = - \frac{dr^2}{1 - \frac{2\mu}{c^2 r}} - r^2 d\theta^2 - r^2 \sin^2 \theta d\phi^2 + \left(1 - \frac{2\mu}{c^2 r}\right) c^2 dt^2.$$

The general solution has not yet been obtained. Other particular solutions may also be possible.

The differential equation involves a constant equal to the velocity of light. As the gravitational effect is experienced by planets over millions of years, not necessarily observed by Man, there is no reason why the velocity of light should enter into the orbital equation. One may on the other hand expect that the constant of velocity is the velocity of gravitational influence. But in Relativity the velocity of gravitation has no meaning at all; it is neither infinite nor definite, as Eddington has said, "If co-ordinates are chosen so as to satisfy a certain condition which has no clear geometrical importance the speed is that of light; if the co-ordinates are slightly different, the speed is altogether different from that of light. The result stands or falls by the choice of co-ordinates."

POSTULATE No. XL — *A gravitational field of force is precisely equivalent to artificial field of force, so that in a small region it is impossible to distinguish between the two.*

The artificial field of force (e.g., centrifugal force) can vary according to the system of co-ordinates chosen. But in a large region it is not at all possible to get rid of it altogether by any choice of co-ordinates. There is an irreducible field of force which can only be ascribed to gravitation.

POSTULATE No. XLI. — *The principle of action at a distance is false; a field theory is real.*

But if action at a distance is denied then there are only two possible ways in which influence can reach a distant point. Either some thing travels bodily, or there is a medium which conveys it. If we deny both these, a field at a distance cannot come into existence at all.

Although denying the existence of any material medium or ether, Relativity has to attribute to Space definite properties, for example that of curvature, thus making

Space no longer the bare void of old, but possessing properties, like a medium. The world no longer consists of particles of matter or electricity with featureless inter-spaces, and an army of mathematical symbols is now required to describe what is going on in these inter-spaces. The ether itself is as much in the fore as ever it was before. Thus while destroying the old ether, Relativity has created a new species of ether, under the nomenclature of a new kind of Space endowed with mysterious properties.

POSTULATE NO. XLII—*Space-Time is not flat but is either (1) cylindrical 2) spherical or (3) elliptical*

The old Euclidean Geometry has had to be completely over-thrown and discarded. This new kind of Space is boundless yet limited and finite, because it bends upon itself and so gets ultimately closed up to form a finite domain. The old philosopher may well ask: If Space is finite, what is beyond it? A Relativist would say that beyond it is non-Space. But according to old ideas, even that non-Space was Space itself as though not actually occupied by anything, it was capable of being occupied by something. Of course, if it were the finiteness of the material world it would be comprehensible.

Einstein's world is cylindrical - curved in three space dimensions, but straight in time dimension. Straight lines do not go straight, but get curved, and bending upon themselves return to their starting points in a definite period. But if space is not absolute, to what points do they return? And if time is not absolute, in what period do they return?

De Sitter's world is spherical, with all dimensions curved. Time runs faster and time-clocks slow down with distance. Space is finite and yet its finite limit is incapable of being reached except in infinite Time, because Time is made to slow down with distance and ultimately becomes stationary at about half-way. In this part of the World nothing ever happens, everything remains for ever just as it is. Hence it becomes the abode of immortals, as change being impossible even death cannot come. There is an eternal barrier of Time which cannot be crossed. Even light cannot complete its voyage round the world. But as everything is relative, people there would find that we here never die.

No body can travel faster than light, and Time itself becomes stationary at this speed. If one were to travel with light at this velocity from a distant nebula and take 150 million years to reach the Earth, the time actually taken in the journey according to him would be exactly nil, for at that speed Time had become stationary. In Quantum Mechanics phase velocity is always greater than that of light. And in an expanding universe, nebulae should after a certain distance acquire velocities greater than that of light.

But these mathematical structures of the world leave it uncertain whether the imaginary curvature of Space is positive, zero or negative, for Relativists are not yet

quite agreed among themselves about it. Einstein's Universe is an unstable Universe—containing a vast quantity of matter uniformly spread throughout Space but having no motion. De Sitter's Universe contains motion but no matter—he has merely swept matter into the distant horizon of Space. Milne applies hydro-dynamical equations of motion and continuity, as if the Universe consists of a huge mass of fluid with all the properties of a perfect fluid. But when the Universe is seen from the inside as we observe it from the Earth, it appears to consist of large condensations of mass moving relatively to one another, and with large empty spaces in between. When thus observed, it has neither Einstein's motionlessness, nor de Sitter's material-lessness, nor Milne's fluidity. The actual Universe which we see has no resemblance to any of these three models.

As each of the four co-ordinates can be either curved or straight, there can be sixteen different models of the world.

POSTULATE No. XLIII.—*The Universe is expanding.*

The Universe was in a state of unstable equilibrium. It started expanding at a tremendous speed, but might well have started shrinking. Einstein has changed his law of gravitation into $G_{\mu\nu} = \lambda g_{\mu\nu}$ where λ is a supposed universal constant. The result of this is that all parts of it are flying away from one another. But at least two nebulae appear to be actually approaching. When asked what is it into which this Universe is expanding, the Relativist would reply that the new four dimensional Space-Time is expanding into a continuum of five dimensions. But does that at all convey any meaning or sense to us? In Dynamical language this supposed expansion would involve the existence of a cosmic force of repulsion between two bodies, which not only acts at a distance, but curiously enough its intensity, instead of decreasing with distance increases as the distance between them increases, with the result that the whole Universe is exploding away. But everything according to Relativity is relative, and so this expanding Universe ought to be an exact equivalent of the shrinking Atom which would mean that the Universe is collapsing at a prodigious rate.

POSTULATE No. XLIV.—*The periods of vibrations of atoms vary with the gravitational field.*

Einstein has derived the period of vibration from the differential equation by assuming "an atom to be momentarily at rest," which it can hardly ever be. This slowing down of the atomic vibration is independent of de Sitter's slowing down with distance.

POSTULATE No. XLV.—*Regions actually occupied by matter are cut out of Space-Time altogether.*

This is because Space-Time conception is unable to account for it. "The existence of an electron contradicts the electro-magnetic laws with which we have to

work at present, so that from the present standpoint an electron at rest in no external field of force is a miracle. An electron in an external field of force having the (derived) acceleration is precisely the same miracle" (Eddington).

POSTULATE NO. XLVI.—*There is no limit for the number of dimensions of Space-Time.*

"The problem of two bodies on Einstein's theory remains an outstanding challenge to mathematicians—like the problem of three bodies on Newton's theory". (Eddington) The motion of the Moon can be determined only by treating the mass of the Moon as infinitesimal, although it is one-eightieth of that of the Earth. The problem of multiple bodies is altogether insoluble. If the interaction of a million stars were to be taken into account, Space would have four million dimensions, because each star has its own separate and independent Spacial and Time co-ordinates which have nothing in common between them.

Further **Postulates** are made for electro-magnetic action, gravitational waves, energy tensor and generalised world structure.

Einstein's POSTULATE appear to be unconvincing; and their acceptance would be difficult when observations show large discrepancies. His mathematical analysis is, however, superb and flawless. It seems as if a magnificent super-structure has been put on unsound foundations. One wonders whether these results might not be mere misinterpretations of Nature, and in reality nothing more than mere artificial mathematical devices for expressing something imperfectly understood. As the assumptions are only approximately true, they give tolerably good results so long as velocities are small compared to that of light; but as they are neither rigorous nor exact, the philosophy based on them is irrational and the deductions incomprehensible.

ADDRESS OF THE PATRON

SPEECH BY HIS EXCELLENCY SIR MAURICE HALLETT, K.C.S.I., C.I.E., I.C.S.,
GOVERNOR, UNITED PROVINCES, AT THE ANNUAL MEETING OF THE
NATIONAL ACADEMY OF SCIENCES, ALLAHABAD,
ON JANUARY 13, 1940

MR. PRESIDENT, LADIES AND GENTLEMEN.

The National Academy of Sciences have done me a great honour by asking me to be their Patron and inviting me here to-day. I must confess that I have accepted this honour with some trepidation, for I feel myself to be very unfit to be the Patron of an Academy of this kind. Having had the benefit of a classical education (perhaps some here would prefer me to say having been handicapped by a classical education) my knowledge of science is infinitesimal, while my knowledge of mathematics is even less, if I may give that somewhat unscientific description of my ignorance. I feel even more ashamed of my ignorance after listening to the addresses given by the President and by the Chairman of the Reception Committee. The President, I understand, regards the study of higher mathematics as a relaxation, for during the many years that he has held with distinction a very high judicial office in this province, he has devoted his spare time to this abstruse study and has set an example which many of us might well follow. Now that he has greater leisure, we may hope that he will be able to make even further valuable investigations into those problems which he has put before us this afternoon.

The Chairman of the Reception Committee, though not a scientist himself, has shown that he has acquired a very good working knowledge of the subject, for at least he knows what the scientist wants to carry out his work. It is indeed unfortunate, to use a somewhat mild term, that the mad policy of one nation, perhaps I should say of one man, apart from its more direct results, has had the indirect result of handicapping throughout the world scientific investigations, such as those which have been carried on by members of this Academy and by students in this University of Allahabad. Many scientists throughout the world are, in view of present conditions, forced to devote their attention to what I may call war problems, many must be occupied in considering what new methods can be devised for destroying human life; but on our side the attention of our scientists is directed rather to the problem of how to protect human life, whether it be threatened from the air, or at sea, or on the fighting front. We cannot help feeling regret at what may appear to be an unprofitable investigation, but we must remember that results obtained in war time may be

put to profitable use when peace is once more restored to this harassed world. When the last Great War started, aeronautics was in its infancy, and it was largely due to experience gained during that struggle that this science made such very rapid progress. Had it not been for the scientists who examined the problems of aerial flight, and the pilots who tested the results of these investigations in practice, it is probable that the world would have had to wait much longer for that efficient system of air communications which exists today and by which this country is brought within a very short distance of Europe and the centre of the British Empire. We may, therefore, be optimistic enough to hope that the investigations which are now being carried on for the purpose of the war will prove profitable to the world at large when peace is again restored.

The Chairman has, however, raised a more practical problem, and as it not infrequently happens when I attend a meeting of any kind, he has put forward a request for financial assistance from Government. His demands appear modest but as some of you may perhaps recognise, the financial position of this province is such that it is not easy to meet even the most moderate demands. He has suggested that chemicals might be manufactured in this University, both for use in the laboratory and for public consumption. It is possible that some of the big industrial undertakings in India might also help in this important work, and the present difficulties which arise of obtaining these articles from foreign countries may facilitate their manufacture on a commercial scale by industrialists in this country. I need not say more on this subject, save to give the Chairman an assurance that his detailed scheme will receive my very careful consideration and that I will certainly do all that is possible to help in this important matter.

When I was considering what I should say on this occasion, my attention was drawn to the speech delivered by a very great predecessor of mine, Lord Hailey, when he attended the inaugural meeting of this Academy some eight years ago. I cannot refrain from referring to that speech. Lord Hailey drew attention to the fact that mere addition to knowledge, as such, does not necessarily make the world happier. He raised doubts whether some improvement in the comparative annihilation of distance or the more rapid transference of thought really made our lives happier. He was speaking eight years ago, long before India was connected with the other parts of the world by an efficient air service, long before "wireless" was as universal as it is to-day. I must admit that I too share those doubts. I recognise, as did Lord Hailey, that improvement in health is a very definite addition to human happiness and we must welcome every discovery by medical scientists which tends to alleviate human suffering. We must also in this country welcome the investigations of agricultural scientists which result in making two blades of grass grow where formerly there was only one, and we recognise with appreciation the work that has been done to improve those crops which are of vital importance to

the cultivator. But the main point of this portion of Sir Malcolm's speech may be made clear by quoting this question which he put to his audience—"Can science do anything to aid the moralist in removing some of the malevolence which does actually seem to form a part of common human nature and which continues to thwart the progress made by the growth of the social sense?" That is a question which is even more pertinent today than it was eight years ago; then tariff wars, economic disputes and difficulties over the problem of disarmament merely created a sense of insecurity which was in itself a source of mischief and unhappiness. We are now beyond the stage when dangers to the peace of the world were anticipated; we are faced with those dangers on every side. It is pertinent to ask the question: Can science help us in the problems which will certainly arise once this war is ended; can science help us to stamp out that evil of malevolence which is the main cause of all these troubles with which we are now confronted? I cannot do better than quote the concluding sentence of Lord Hailey's address when he said; "If we can link up the energies of scientific men with the other agencies which are working for our betterment, then perhaps we may get a synthesis of effort which will mould the human character into something nobler than the shape which it now presents." I too have that optimistic feeling in these dark days and I trust I may be able to preserve it in the even darker days which may lie ahead. If we all strive for the betterment of the human race, whatever may be our particular form of study, that synthesis of effort cannot fail to achieve its object.

VOTE OF THANKS

In proposing the vote of thanks to His Excellency the Patron, Prof. Y. Bhadraraja, M.Sc., Ph.D., F.L.S., F.N.I., Fellow of the National Academy of Sciences, India, spoke as follows :

YOUR EXCELLENCY,

On behalf of the Fellows and the Members of the National Academy of Sciences, India, it is my pleasant duty to offer our thanks to Your Excellency and express our gratefulness that you have been pleased to find time in the midst of your multifarious engagements to preside over this function. Under Your Excellency's kind patronage, this Academy, which has already done good work not only in the dissemination of scientific knowledge, but also in stimulating original investigations and research in various branches of science, will, I am sure, prove itself more useful in the service of the country and the mankind. We feel highly honoured by Your Excellency's presence. The keen interest that Your Excellency has shown in the welfare of the Academy will give great encouragement to all the Members and sympathisers of this Institution. I once again thank Your Excellency for having been pleased to preside over this Annual Meeting.

APPENDIX 1

PROGRAMME OF THE NINTH ANNUAL MEETING OF THE NATIONAL ACADEMY OF SCIENCES, INDIA, ALLAHABAD

Saturday, January 13, 1940

2-55 P.M.—Reception of His Excellency the Patron of the Academy, and Lady Hallett in the portico of the Mayo Hall, by the Members of the Council of the Academy in their academic robes.

3 P.M.—Annual Meeting in the Mayo Hall, Allahabad

- (1) Secretaries' Report.
- (2) Welcome address by the Chairman of the Reception Committee.
- (3) Address by the President of the Academy.
- (4) Speech by His Excellency the Patron of the Academy.
- (5) Presentation of the Education Minister's Gold Medal.
- (6) Announcement of the Office-Bearers for 1940.
- (7) Vote of thanks to His Excellency the Patron of the Academy.

4-30 P.M.—“At HOME” by the Hon'ble Sir Shah Muhammad Sulaiman, Kt., M.A., LL.D., D.Sc., F.N.I., the President of the Academy, to meet His Excellency the Patron and Lady Hallett in the Mayo Hall compound, Allahabad.

5-30 P.M.—Popular lecture on “The Physiological Bases of Right and Wrong” by Dr. W. Burridge, D.M., M.A (Oxon.), Professor of Physiology, King George's Medical College, Lucknow, in the Mayo Hall, Allahabad.

Sunday, January 14, 1940

10-30 A.M.—(1) Meeting of Section I (Chemistry, Physics and Mathematics) under the presidentship of Dr. N. R. Dhar, D.Sc., F.C.S., I.E.S., F.N.I., Deputy Director of Public Instruction, U. P., Allahabad, in the Physics Lecture Theatre of the University.

(a) Presidential Address

(b) Reading of and discussion on original papers.

(2) Meeting of Section II (Zoology, Botany, Geology and Agriculture) under the presidentship of Prof. B. Sahni, D.Sc., Sc.D., F.G.S., F.R.S., F.N.I., Professor of Botany, Lucknow University, Lucknow, in the Botany Lecture Theatre of the University.

Reading of and discussion on original papers.

6-30 P.M.—Popular lecture on “New ideas and practices in land improvement” by Dr. N. R. Dhar, D.Sc., F.C.S., I.E.S., F.N.I., Deputy Director of Public Instruction, U. P., in the Physics Lecture Theatre of the University.

8 P.M.—Dinner in the Vizianagram Hall, Muir College Buildings, Allahabad.

Monday, January 15, 1940

10-30 A.M.—(1) Meeting of Section I in the Physics Lecture Theatre of the University.

(a) Lecture on “The nature of degradation of the strychnine molecule” by Dr. R. H. Siddiqui, M.Sc., Ph.D., D.Phil., Chemistry Laboratory, Muslim University, Aligarh (U. P.).

(b) Reading of and discussion on original papers.

(2) Meeting of Section II in the Botany Lecture Theatre of the University.

(a) Presidential Address

(b) Reading of and discussion on original papers

2-15 to 4-14 P.M.—Excursion to the Allahabad Agricultural Institute, Naini. Exhibition.

Members willing to go to the Naini Agricultural Institute are requested to assemble in the Botany Department of the University at 2-15 p.m. sharp on Monday, January 15, 1940.

4-15 P.M.—Tea by the Principal and the Staff of the Allahabad Agricultural Institute, Naini.

APPENDIX 2

DONORS

1. The Rt. Hon'ble Sir Tej Bahadur Sapru, Kt., P. C.
2. The Hon'ble Sir Shah Muhammad Sulaiman, Kt.
3. Pandit Amaranatha Jha, M.A., F.R.S.L.
4. Rai Bahadur Pandit Kanhaiya Lal.
5. B. Malik Esq., Barrister-at-law.

APPENDIX 3

RECEPTION COMMITTEE

Chairman

PANDIT AMARANATHA JHA
Vice-Chancellor, Allahabad University

Secretary

DR. SHRI RANJAN, M.Sc., D.Sc.

Assistant Secretary

DR. R. K. SAKSENA, D.Sc.

Members

- | | |
|--|--|
| 1. Dr. N. R. Dhar, D.Sc. I.E.S. | 24. Capt. S. M. Zamin Ali, M.A. |
| 2. Prof. D. R. Bhattacharya, D.Sc.,
Ph.D., F.Z.S. | 25. Mr. K. K. Bhattacharya. |
| 3. Prof. A. C. Banerji, M.A., M.Sc.,
I.E.S. | 26. Mr. K. R. R. Shastri |
| 4. Prof. J. H. Mitter, M.Sc., Ph.D. | 27. Mr. B. P. Adarkar, M.A. |
| 5. Prof. Saligram Bhargava, M.Sc. | 28. The Hon'ble Mr. P. N. Sapru. |
| 6. Prof. K. P. Chatterji, M.Sc. | 29. Mr. K. K. Mehrotra, M.A. |
| 7. Prof. A. Siddiqui, D.Litt. | 30. Mr. B. G. Bhatnagar, M.A. |
| 8. Prof. A. P. Dube, Bar-at-law. | 31. Dr. Ram Saran Das, D.Sc. |
| 9. Prof. S. K. Rudra, M.A. | 32. Mr. S. C. Varma, M.Sc. |
| 10. Prof. Beni Prasad, D.Sc. | 33. Dr. B. N. Prasad, D.Sc., Ph.D. |
| 11. Prof. Shiva Adhar Pande, M.A. | 34. Capt. S. G. Tiwari, M.A. |
| 12. Mr. M. S. Randhawa, I.C.S. | 35. Dr. G. B. Deodhar, Ph.D. |
| 13. Dr. S. P. Varma, M.A., Ph.D. | 36. Mr. G. D. Srivastava. |
| 14. Dr. H. R. Mehra, Ph.D. | 37. Dr. S. K. Dutta, D.Sc. |
| 15. Dr. S. B. Dutt, D.Sc., P.R.S. | 38. Dr. K. Majumdar, D.Sc. |
| 16. Dr. Gorakh Prasad, D.Sc. | 39. Dr. Satyeshwar Ghosh, D.Sc. |
| 17. Rai Sahib Dr. P. L. Srivastava,
M.A., D.Phil. | 40. Dr. Umesh Misra, D.Litt. |
| 18. Dr. R. N. Ghosh, D.Sc. | 41. Mr. Daya Shankar Dubey, M.A. |
| 19. Dr. Iqbal Kishen Taimini, Ph.D. | 42. Mr. Lila Dhar Gupta, M.A. |
| 20. Dr. Ram Prasad Tripathi. | 43. Mr. K. D. Tiwari, M.A., LL.B. |
| 21. Mr. A. C. Mukerji, M.A. | 44. Capt. Dr. P. G. Ghosh. |
| 22. Mr. S. C. Deb, M.A. | 45. Mr. D. H. Ramchandra Rao, B.E. |
| 23. Mr. G. D. Karwal, M.A. | 46. Dr. A. K. Bhattacharya, D.Sc. |
| | 47. Mr. I. D. Dharni. |
| | 48. Mr. G. N. Kapur. |
| | 49. Mr. Balgovind Das, C/o Lallooji
and Sons. |

APPENDIX 4

THE PHYSIOLOGICAL BASES OF RIGHT AND WRONG

By W. BURRIDGE, D.M., M.A. (OXON.).

PROFESSOR OF PHYSIOLOGY, KING GEORGE'S MEDICAL COLLEGE, LUCKNOW

LADIES AND GENTLEMEN,

This evening I wish at the outset to introduce you to the idea that the brain is an instrument or machine with which we do our thinking. To appreciate that it is such an instrument is of the highest importance and some idea of this importance can be gathered by considering the following little tale.

Imagine to yourself an inhabitant of Mars who has flown through space and alighted on one of those corner buildings overlooking the four cross roads in Johnstongunj. From his coign of vantage he watches the policeman directing the traffic which in a modern city like Allahabad consists solely of motor cars! After watching the flow of traffic for some time he begins to speculate on what he has seen, but his speculations have to be done without knowing that motor cars are self-propelling vehicles, and that they have drivers. I would therefore ask each of you next to consider what reasonable conclusions can the Martian draw from the facts which he has observed. So far as I can judge, the only conclusions that he can reach are that a waving policeman's arm somehow or other confers motion on these vehicles, and that when held in a certain position it inhabits the movement of motor cars.

These conclusions are correct so far as they go. Beyond that, in absence of knowledge of the mysteries of motor cars, our imaginary Martian can but speculate how a policeman's arm can exert these powers, and only by chance can he get at the truth in absence of knowledge of the workings of motor cars.

Now, when any one of you starts thinking about any problem, or examines his conscience, or does anything of that sort, you are exactly in the position of that imaginary Martian watching the traffic. For when we start thinking we see a succession of mental pictures, but we see nothing of the machinery which produces the pictures. And unless we are acquainted with the picture-producing machinery we can get no further than our imaginary Martian framing hypotheses concerning the powers in the policeman's arm.

Such being the case any one plausible theory of the powers possessed by the policeman's arm is as good as any other. Consequently, after anyone has

produced a plausible theory about this he tends to become the founder of a school of thought. Each school will accept as an axiom the belief that the policeman's arm possesses certain mystic powers, they will differ among themselves concerning the nature of the powers and how they are exerted. You may take it that what is termed the New Psychology is based on accurate observation of cerebral traffic control, but nowhere gets further than ascribing powers to the policeman's arm. You may further take it that any school of psychology, which does not everywhere endeavour to correlate psychological phenomena with the activities of the machinery provided to us to do our thinking, gets no further than speculating about the powers of the policeman's arm. Introspection and direct observation likewise get one no further.

A further essential to an understanding of the cerebral machinery is to put aside all one's desires and hates and take the detached view. We can do this fairly simply if we look on the brain as a television-talkie apparatus reproducing inside that brain the results of activating its various receivers. The eye, for example, is not the place where we see. It is the receiver or periscope for surveying the outer world, and the impressions which it receives from that outer world are transmitted through nerves to the television screen in the brain. I cannot give you the slightest idea as to where that screen is or what it is. I can only tell you that a television screen is the nearest approximation to the nature of the mechanism actually involved.

Once, however, one has grasped the idea that the brain somehow or other acts as a television-talkie apparatus, it simplifies progress to the next stage where we appreciate that the machinery can go wrong.

Now the machinery presents us with two groups of pictures, those of impressions actually being received at any moment from the world around us and those of our memories. In respect of memories the brain can be regarded as a combination of gramophone and cinema film.

Everyone is born to place implicit faith in what he sees and in what he remembers. But also it is the rule for men to effect artificial alterations in their mental pictures and they do so by drugs. As a rough generalization with many exceptions, the West effects these changes through alcohol, and the East through opium.

The drunk man, however, has the same implicit faith in the altered pictures presented to him by the altered activities of his cerebral machinery as he had in the pictures which it presented to him when he was sober. Also, as when sober, his actions strictly accord with the pictures that he actually sees. His actions therefore change because the pictures are changed.

Insanity is also based on altered pictures, but with the alteration effected in these cases by disease processes. These disease processes alter the working of the cerebral machinery and so produce distorted pictures and ideas. The insane

individual believes in the distortions which he finds just as sane people believe in what they find. But the insane's actions accord with the distorted pictures that he finds.

I draw your attention to insanity and drunkenness because of the evidence afforded by them of the fact that an individual's ideas of what is right and wrong can be changed by processes that are essentially earthly as opposed to what is termed spiritual. We must possess inside our brains some mechanism, differentiating between right and wrong, which so pertains to the flesh that its activities can be changed by such a material agent as alcohol. Consequently the more we can learn about the mode of action of alcohol on living structures the more we shall learn about the nature of the mechanism that differentiates in us between right and wrong. Experiments with alcohol done in Lucknow throw considerably new light on the actions of alcohol on living structures.

We may now digress to point out that men everywhere in this world divide things into the good, bad and indifferent. This division, however, is not inherent to the things themselves but to the minds that make the division. For when we survey the world what we actually survey is a series of pictures presented to us by the processes at work in our organs of mind. Consequently instead of looking for evil in the thing itself we should search for some particular type of cerebral activity mediating to us the idea of evil and good, respectively. Further, since all men make this division into the good, bad and indifferent, we should, for it is something inherent to the nature of the machinery with which we do our thinking. This, of course, is an inversion of the usual sequel of argument. Hitherto it has been the rule for men to seek the solution of the problem of good and evil in the world external to them. Now, because we find that all men believe in the good and the evil, we deduce that there must be something in the nature of the thinking machinery that makes the division for them. Accordingly we seek a machinery that would do it. The machine capable of this has the nature of a one-stringed musical instrument. Medical men would call this instrument a rhythmical structure, but for purposes of popular exposition it may be regarded as an instrument always undergoing waves of activity or producing vibrations at so many cycles per second. Somewhere or other we have a receiving apparatus which transforms these vibrations into music, or vision, and so on.

We have, however, a limited capacity to interpret these vibrations and information on this is afforded by the known phenomena of sound. Most of you are doubtless aware that a musical note is based on vibrations set up in the air by the instrument emitting, and that these air vibrations are detected by the ear.

Now, if middle C be accepted as the note produced by a wire or string vibrating at 256 times per second, then, wires which vibrate at 255 and 257 actually produce different notes. We, however, cannot directly appreciate these others as different

notes. We must still call them C, yet we appreciate also that they are somewhat sharp or flat respectively. Eventually of course, sharp C becomes C sharp, but none can exactly distinguish where sharp C ends and C sharp begins.

When, then, we interpret the vibrations or cycles of activity taking place in our brains, we do not detect individual wave-lengths as it were, but lump a whole group together and regard them as generally alike but with minor differences between them.

A rhythmically active nerve cell provides the same possibilities as does a one-stringed musical instrument. First of all, it possesses a normal or neutral rate of vibration, as it were, from which only two variations are possible, namely, quickening or slowing. An agent quickening these rates in living structures is warmth, whereas cold slows them. If, then, the mechanism be of this type we should find warmth in one group of ideas and be cold to the other. I take it that everybody in my audience warms to what he finds good, and finds cold in evil. These associations, you will now appreciate, have more in them than has so far been realized.

If we next bring to account that limited capacity of the human mind to appreciate differences between neighbouring vibrations which music teaches us, you will appreciate that the machinery provided three zones of feeling tone; a zone of cold tones, a zone of neutral tones, and a zone of warm tones. That is to say, it provides the triple division of the good, bad and indifferent.

If we had been provided with such a machinery as has just been depicted, you can easily understand that it can run wrongly in two chief ways. A disease process or drug might quicken up everything, or everything might be slowed. If everything were quickened, the affected individual would be supremely happy for he would find no evil in his world. Actually he does become supremely happy but he has to be sent to a mental hospital because the man who finds no evil in anything he says or does is unfit to associate with people who believe otherwise. In contrast with this, when everything is slowed, the affected individual can find nothing but evil in his world. He also has to be sent to a mental hospital, this time to prevent the man from committing suicide. The next time any member of my audience finds himself in a fit of the blues he will perhaps, appreciate what is happening inside him.

So far I have only been able to outline one element of the machinery with which we do our thinking. It is also the case that this machine has a limit of power, as have other machines, and that this power is derived from two sources of energy. Further, these two sources of energy act together just as do the petrol and air in a motor car. The one source of energy gives us judging capacity, the other source provides us with the data we judge. Consequently, because of the limited capacity of the machine, when the data-energy presented to us for judging becomes sufficiently intense we cannot apply enough judging-energy to it to judge it properly. You will perhaps, appreciate this if you

imagine yourself seated at a proper distance from a large loud-speaker whence a tune is being emitted. The proper distance, of course, is that at which the music is correctly heard or judged. If you next imagine yourself placing your head inside the loud-speaker you will appreciate that your capacity to judge the music will probably be thereby considerably decreased. This capacity is decreased because the great loudness provides great data-energy and so also leaves no room as it were for adequate application of judging-energy. You will find that the same holds true of other sensations.

These two sources of energy have, of course, been recognized by men for ages as the result of their investigations into the pictures presented to them by their organs of mind. In the new psychology one of them was termed by Freud a reality principle, and the other a pleasure-pain principle. Unfortunately, however, they have so far been regarded as antagonists instead of co-operators.

These two sources of energy also provide the bases for our conceptions of time and space, which are for us the great realities. I draw your attentions to this because it is certain that there will be some among my audience who will find my lecture too materialistic. I would therefore close on a different note.

Space and time are for us the great realities, and we are brought into contact with them through the possession by our thinking machinery of two sources of energy. So long also as we fail to appreciate the limitations of our thinking machinery we can but believe that they are the only realities. Once, however, we appreciate that our contact with them is based on the possession by our thinking machinery of two sources of energy, we can begin to doubt if they are the only realities. We are prepared indeed to believe that there may be other realities of which our minds can form no conception solely because of the fundamental limitations of the processes which underlie our thinking. However self-satisfying it may be, then, to imagine that there can be no realities beyond those that we can grasp, a realization of the inherent limitations of our thinking machinery should induce us to use great care before we deny the possible existence of other realities.

NEW IDEAS AND PRACTICES IN LAND IMPROVEMENT

By DR. N. R. DHAR, D.Sc., F.I.C., I.E.S., F.N.I.

DEPUTY DIRECTOR OF PUBLIC INSTRUCTION, U.P.

It is well known that the crop yield in India is in general much less than in other countries as is evident from the following figures :—

For rice the figures are as follows :—

India	...	...	...	1,295 lbs. per acre
Japan	...	...	...	3,040 " " "
Egypt	...	...	...	2,783 " " "

The yield of cotton per acre is—

India	...	...	...	87 lbs.
America	...	...	...	155 "
Japan	...	...	...	181 "
Egypt	...	...	...	371 "

Average yield of wheat

India	...	...	...	605 lbs. per acre
Japan	...	...	...	1,526 " " "
Egypt	...	...	...	1,530 " " "
Canada	...	...	...	2,202 " " "

While for sugar comparative returns are:—

India	...	...	...	2,400 lbs.
Japan	...	...	...	3,340 "
Egypt	...	...	...	3,378 "
Java	...	...	...	11,988 "
Hawaii	...	...	...	18,799 "

It is clear that the fundamental need for India is to ensure a greatly increased return of the cultivation of the soil. By improving the agriculture the standard of living can be raised.

It is estimated that the expenditure on fertilisers in Great Britain is approximately 20 % of the gross outturn of the crop which is believed to fetch a price of 250 million pounds a year. In India the value of the crop produced is estimated to be twelve hundred crores of rupees but the money spent on fertilisers is almost

insignificant. The chief defect of the Indian soil is the paucity of its combined nitrogen content; the nitrogen content of the Indian soil is generally half that of European soils and the manurial problem for India is an adequate supply of nitrogenous manure

Researches carried on for a number of years in the Allahabad University Chemical Laboratory have established that the nitrogen content of a soil is intimately connected with the carbon supply. The carbonaceous compound can fix the atmospheric nitrogen and thus increase the nitrogen content of the soil and also retards loss of nitrogen in the form of nitrogen gas from the soil. From a very long time some people have emphasised the importance of organic manures but the true function of carbonaceous substances in the soil has been discovered in the Allahabad University Chemical Laboratory.

Even as early as the middle of the last century, Liebig stated as follows regarding ancient Rome:—

“The sewers of the immense metropolis of the Ancient World engulfed in the course of centuries the prosperity of the Roman peasants, and when the fields of the latter would no longer yield the means of feeding her populations, these same sewers devoured the wealth of Sicily, Sardinia, and the fertile lands on the coast of Africa.”

Describing mediæval agriculture in England Prothero wrote:—

“There was little to mitigate, either for man or beast, the horrors of winter scarcity. Nothing is more characteristic of the infancy of farming than the violence of its alterations. On land which was inadequately manured, and on which neither field turnips nor clovers were known till centuries later, there could be no middle course between the exhaustion of continuous cropping and the rest cure of barrenness.”

Due to the pioneering efforts of the late Prof F. Haber, large quantities of ammonium salts are manufactured in most countries but the problem of agriculture and of nitrogen conservation cannot be met specially in tropics by the provision of mineral compounds on any scale brought about by rapid industrial developments, as the nitrogen added as ammonium salts is lost readily from soils specially under tropical conditions.

In a review of work on organic manures by Dr. G. Ruschmann (1933) in Biedermann's Central Blatt the following statement occurs:—

“The Humus Question:—The humus economy is not only for Germany but for all civilized European States with their extensive agriculture, an ever burning question. The evils of one-sided measures for manuring assume continually more obvious forms. However much mineral manures serve to increase the yield for the moment, so much the less can they safely maintain their position. This knowledge is spreading both among scientists and practical men. In spite of constant or increasing rise of mineral manures, yields are decreasing.

The increase of soil fertility which is the aim of all modern scientific and practical effort cannot be attained by mineral manures. These by accelerating the breaking down of humus, are actually detrimental. Increase of crop by improving the soil properties, and greater returns by addition of plant foods are two different things which are often confused. The latter can be effected by mineral manures which act immediately. On the other hand, to build up a good soil is a more lengthy process. While it is relatively simple to maintain the fertility of soil rich in humus it is difficult in a soil which is mainly mineral to build up the necessary humus.

Arable soil is a living thing. The complaints of insufficient or completely negative results with mineral manures are rapidly increasing.

The humus capital of German soil has, according to Lohuis, a value of 30 milliards of Reichs-marks although Germany possesses mainly sandy soil. To increase this capital by skill is the important task of both the agricultural and business community. Humus capital puts every other kind of soil wealth on one side. Directly or indirectly all plant and animal life is made possible by the soil humus. To its increase may be systematically employed all those organic materials which at present are virtually wasted. The greatest attention should be devoted to the albuminous or nitrogen containing organic rejection and residues of human and animal life which are admirably suitable for increasing the formation of humus in the soil. Unfortunately we are today still far from the general knowledge of what great importance attaches to all organics and the energy contained in them which comes to us through the sun's rays, and which is set free by the decomposition of these substances in the soil."

THE PROBLEM OF NITROGEN SUPPLY TO PLANTS

It is well-known that the carbon content of plants is derived through the agency of sunlight. From the following arguments it will be seen that the nitrogen requirement of plants and consequently of animals are also due to the sunlight. In the recent publications from these laboratories it has been established that when energy materials like carbohydrates, fats and cellulosic substances are added to the soil, nitrogen fixation takes place which is always found to be greater in the basins and plots exposed to sunlight than in those kept covered although the numbers of *Azotobacter*, total bacteria and fungi are less in the former than in the latter under identical conditions. The following experimental results support the above important conclusion.

TABLE

1 kilogram soil + 20 gms fructose.

Exposed (Temperature 34°-42°).

Date.	NH ₃ - N %	NO ₃ - N %	T. N. %	T. C. %	Moisture %	Azotobacter per gram of dry soil in millions
8-10-36						
original soil	0.0014	0.0032	0.0570	0.6156	1.95	5.2
25-10-36	0.0016	0.0032	0.0570	1.3560	3.1	6.1
11-11-36	0.0021	0.0032	0.0586	1.2622	3.6	13.2
1-12-36	0.0028	0.0032	0.0608	1.1518	3.0	19.8
17-12-36	0.0033	0.0032	0.0622	1.0264	3.6	36.0
31-12-36	0.0042	0.0033	0.0636	0.8978	3.1	34.5
19-1-37	0.0045	0.0033	0.0646	0.7614	3.2	29.8
5-2-37	0.0042	0.0033	0.0656	0.6346	3.5	23.5
22-2-37	0.0038	0.0033	0.0646	0.6284	3.0	15.0
7-3-37	0.0030	0.0033	0.0636	0.6126	3.5	10.5
29-3-37	0.0027	0.0037	0.0626	0.6028	3.0	7.0

Nitrogen fixed per gram of carbon oxidised = 11.9 mgm.

TABLE

1 kilogram soil + 20 gms fructose

Dark (Temperature 22°-31°).

Date	NH ₃ - N %	NO ₃ - N %	T. N. %	T. C. %	Moisture %	Azotobacter per gram of dry soil in millions
8-10-36						
original soil	0.0014	0.0032	0.0570	0.6156	1.9	5.2
25-10-36	0.0015	0.0032	0.0570	1.3745	4.8	7.2
11-11-36	0.0016	0.0032	0.0570	1.3161	4.7	19.8
1-12-36	0.0018	0.0029	0.0590	1.2429	4.3	35.8
17-12-36	0.0021	0.0029	0.0600	1.1633	4.8	82.5
31-12-36	0.0025	0.0029	0.0608	1.0818	5.0	136.5
19-1-37	0.0028	0.0029	0.0612	0.9876	4.5	225.5
5-2-37	0.0025	0.0029	0.0618	0.8434	4.0	260.0
22-2-37	0.0024	0.0031	0.0618	0.7318	4.5	275.0
7-3-37	0.0024	0.0034	0.0622	0.6126	4.0	290.0
29-3-37	0.0022	0.0033	0.0612	0.6028	4.0	210.0

Nitrogen fixed per gram of carbon oxidised = 6.8 mgm.

TABLE

Plot 4 ft. by 4 ft. Containing 4 kilograms starch.

Exposed.

Date	T. N %	T. C %	Moisture %	Azotobacter per gram of dry soil in millions	Total bacteria per gram of dry soil in millions.
13-2-37					
original soil	0.0311	0.3374	1.5	1.5	13.5
15-2-37	0.0325	1.1586	...	...	...
12-3-37	0.0333	1.0622	3.0	6.5	26.0
2-4-37	0.0350	0.9636	3.5	20.5	65.0
27-4-37	0.0365	0.8618	4.0	48.0	140.0
24-5-37	0.0388	0.7412	3.0	75.0	195.0
10-6-37	0.0407	0.5792	3.5	70.0	230.0
11-7-37	0.0424	0.5594	...	76.0	215.0
27-9-37	0.0411	0.4684	4.0	35.0	175.0

Nitrogen fixed per gram of carbon oxidised = 16.5 mgm.

TABLE

Plot 4 ft. by 4 ft. Containing 4 kilograms starch.

Covered.

Date	T. N. %	T. C. %	Moisture %	Azotobacter per gram of dry soil in millions.	Total bacteria per gram of dry soil in millions.
13-2-37					
original soil	0.0420	0.4360	1.5	1.5	13.5
15-2-37	0.0437	1.2488	...	...	...
12-3-37	0.0437	1.1924	4.0	8.5	31.5
2-4-37	0.0446	1.1178	4.5	35.5	85.5
27-4-37	0.0456	1.0214	4.0	70.0	205.0
24-5-37	0.0462	0.9258	3.5	105.0	215.0
10-6-37	0.0466	0.8205	4.5	130.0	282.3
11-7-37	0.0472	0.7036	4.0	155.0	345.0
27-9-37	0.0482	0.4864	4.8	162.6	350.8

Nitrogen fixed per gram of carbon oxidised = 5.9 mgm.

TABLE

1 kilogram soil + 20 grams filter paper

Exposed.

Date	NH ₃ -N %	NO ₃ -N %	T. N. %	T. C. %	Moisture %	Azotobacter per gram of dry soil in millions.
30-10-36						
original soil	0.0011	0.0020	0.0540	0.567	2.2	2.4
22-12-36	0.0008	0.0018	0.0540	...	3.8	3.7
20-1-37	0.0007	0.0016	0.0560	...	3.1	7.7
20-3-37	0.0006	0.0014	0.0583	...	3.0	12.5
7-5-37	0.0006	0.0012	0.0646	...	3.5	20.5
7-6-37	0.0006	0.0011	0.0677	...	3.1	27.2
8-7-37	0.0007	0.0014	0.0666	0.7012	...	18.0
13-9-37	0.0014	0.0021	0.0646	0.6704	...	12.0

Nitrogen fixed per gram of carbon oxidised = 18.1 mgm. (calculated)

TABLE

1 kilogram soil + 20 grams filter paper

Dark.

Date	NH ₃ -N %	NO ₃ -N %	T. N. %	T. C. %	Moisture %	Azotobacter per gram of dry soil in millions.
30-10-36						
original soil	0.0011	0.0020	0.0540	0.5670	2.2	2.4
22-12-36	0.0007	0.0015	0.0540	...	4.8	4.3
20-1-37	0.0006	0.0012	0.0540	...	4.2	5.7
20-3-37	0.0006	0.0011	0.0552	...	4.0	25.5
7-5-37	0.0006	0.0009	0.0567	...	3.0	60.0
7-6-37	0.0006	0.0009	0.0575	...	...	80.0
8-7-37	0.0006	0.0009	0.0583	...	...	92.5
13-9-37	0.0008	0.0001	0.0608	0.6486	...	145.0

Nitrogen fixed per gram of carbon oxidised = 9.2 mgm. (calculated).

TABLE

1 kilogram soil + 50 grams cowdung.

Exposed.

Date	T. N. %	T. C. %	Moisture %	Azotobacter per-gram of soil in millions	Total bacteria per gram of dry soil in millions.	Fungi per gram of dry soil.
5-2-37						
original soil	0.0323	0.3180	1.8	2.05	12.5	28000
6-2-37	0.0448	0.9286	...	...	...	...
2-3-37	0.0460	0.8418	2.5	6.5	26.0	25000
25-3-37	0.0493	0.7392	3.0	15.0	50.0	28000
19-4-37	0.0525	0.6036	2.5	22.5	110.0	21000
17-5-37	0.0532	0.5194	3.0	20.0	100.0	18000
1-6-37	0.0525	0.5086	3.9	16.0	80.0	18000
7-7-37	0.0508	0.4928	2.5	9.5	65.0	19000

Nitrogen fixed per gram of carbon oxidised = 20.53 mgm.

TABLE

1 kilogram dry soil + 50 grams cowdung

Dark.

Date	T. N. %	T. C. %	Moisture %	Azotobacter per gram of soil in millions.	Total bacteria per gram of dry soil in millions.	Fungi per gram of dry soil.
5-2-37						
original soil	0.0323	0.3180	1.8	2.05	12.5	28000
6-2-37	0.0453	0.9312	...	...	...	...
2-3-37	0.0453	0.8648	3.5	7.0	21.0	32000
25-3-37	0.0460	0.7862	4.0	20.0	75.0	46000
19-4-37	0.0473	0.6654	3.5	50.5	210.0	44000
17-5-37	0.0480	0.5480	4.0	62.0	245.0	40000
1-6-37	0.0480	0.5194	3.0	52.0	238.0	26000
7-7-37	0.0473	0.4928	3.0	40.0	220.0	30000

Nitrogen fixed per gram of carbon oxidised = 6.5 mgm.

TABLE

1 kilogram soil + 20 grams butter.

Exposed.

Date.	NH ₃ -N. %	NO ₃ -N. %	T. N. %	T. C. %	Moisture. %	Azotobacter per gram of dry soil in millions.
13-10-36						
original soil	0.0014	0.0032	0.0570	0.6156	1.8	5.1
14-11-36	0.0015	0.0032	0.0570	1.4195	2.6	5.8
15-12-36	0.0016	0.0032	0.0570	1.3883	3.1	7.6
13-1-37	0.0014	0.0029	0.0570	1.3497	3.5	9.5
18-2-37	0.0009	0.0024	0.0591	1.1968	3.9	12.0
11-5-37	0.0007	0.0011	0.0617	0.9381	3.0	35.0
11-9-37	0.0006	0.0010	0.0646	0.6654	3.0	25.0
12-10-37	0.0009	0.0011	0.0626	0.6318	3.2	15.6

Nitrogen fixed per gram of carbon oxidised = 10.07 mgm.

TABLE

1 kilogram soil + 20 grams butter.

Dark.

Date.	NH ₃ -N. %	NO ₃ -N. %	T. N. %	T. C. %	Moisture. %	Azotobacter per gram of dry soil in millions.
13-10-36						
original soil	0.0014	0.0032	0.0570	0.6156	1.8	5.1
14-11-36	0.0014	0.0032	0.0570	1.4161	3.9	6.6
15-12-36	0.0015	0.0030	0.0570	1.4278	4.0	8.5
13-1-37	0.0012	0.0028	0.0570	1.3962	4.4	14.6
18-2-37	0.0007	0.0021	0.0583	1.2854	4.0	20.0
11-5-37	0.0006	0.0010	0.0591	1.0952	4.0	50.0
11-9-37	0.0006	0.0009	0.0600	0.7456	3.5	70.0
12-10-37	0.0007	0.0009	0.0591	0.6036	3.8	18.8

Nitrogen fixed per gram of carbon oxidised = 4.22 mgm.

TABLE

Plot 4 ft. by 4 ft. containing 2 kilograms of ghee (clarified butter).

Exposed.

Date.	T. N. %	T. C. %	Moisture. %	Azotobacter per gram of dry soil in millions.	Total bac- teria per gram of dry soil in millions.	Fungi per gram of soil
26-1-37						
original soil	0.0368	0.3901	1.6	1.35	14.5	29000
28-1-37	0.0368	1.0797	...	...	...	...
6-4-37	0.0381	0.9876	2.5	7.5	32.5	38000
4-5-37	0.0392	0.8873	3.0	20.0	95.5	30000
26-5-37	0.0400	0.8136	3.5	46.5	160.5	3 000
14-6-37	0.0407	0.7194	..	40.0	196.0	33000
22-9-37	0.0437	0.4528	3.3	38.4	205.8	28000
27-10-37	0.0420	0.4318	4.8	20.6	175.6	27000

Nitrogen fixed per gram of carbon oxidised = 11.0 mgm.

TABLE

Plot 4 ft. by 4 ft. containing 2 kilograms of ghee.

Covered.

Date.	T. N. %	T. C. %	Moisture.	Azotobacter per gram of dry soil in millions.	Total bac- teria per gram of dry soil in millions.	Fungi per gram of soil.
26-1-37						
original soil	0.0381	0.4115	1.6	1.34	13.6	28000
28-1-37	0.0381	1.0941	...	...	...	...
6-4-37	0.0381	1.0312	3.0	8.5	64.0	45000
4-5-37	0.0388	0.9487	4.0	32.5	175.0	48000
26-5-37	0.0392	0.8906	4.0	66.0	245.0	46000
14-6-37	0.0400	0.8205	3.0	85.0	295.0	42000
22-9-37	0.0411	0.5316	5.0	94.0	330.0	40000
27-10-37	0.0411	0.4424	5.0	68.5	290.0	35000

Nitrogen fixed per gram of carbon oxidised = 4.6 mgm.

Experiments with other energy materials like molasses, hay and butter added to field soil gave similar results. In the control fields no fixation of atmospheric nitrogen was observed. The nitrogen fixation with cellulosic substances is a very important phenomenon since the bulk of the energy materials added to the soil consists of cellulose. The fixation of nitrogen with fats is entirely a new observation and is important since fats are distributed in the plant residues that are added to the soil.

In many experiments it has been established that the energy materials, when added to the soil are oxidised liberating energy which is utilised in nitrogen fixation according to the equation $N_2 + O_2 + 43'2 \text{ K Cal} = 2NO$. This endothermal chemical change can take place through the absorption of chemical energy derived from the oxidation of the energy materials; $C_6H_{12}O_6 + 6O_2 = 6CO_2 + 6H_2O + 676 \text{ K Cal}$. When the system is exposed to sunlight, the light is absorbed and causes an increase in the nitrogen fixation and that is why the nitrogen fixation in light per gram of carbon oxidised is much greater than in the dark as is clear from the following table:—

TABLE

Substance	Nitrogen fixed per gram of carbon oxidised.	
	Exposed	Dark.
Canesugar (2 %) + $CaCO_3$	15.8 mgm	10.5 mgm
Canesugar (2 %)	14.6 mgm	10.2 mgm
Glucose (2 %) + $CaCO_3$	12.5 mgm	6.5 mgm
Glucose (2 %)	12.5 mgm	6.5 mgm
Glycerol (5%)	6.04 mgm	2.76 mgm
Starch (5%)	7.58 mgm	3.13 mgm
Mannitol (2 %)	12.8 mgm	6.9 mgm
Dextrin (2%)	12.03 mgm	5.92 mgm
Fructose (2%)	11.9 mgm	6.8 mgm
Maltose (2%)	12.6 mgm	6.5 mgm
Galactose (2 %)	12.09 mgm	6.7 mgm
Cowdung (5 %)	20.53 mgm	6.5 mgm
Butter (2 %)	10.07 mgm	4.22 mgm

Field trials.

Substance.	Nitrogen fixed per gram of carbon oxidised.	
	Exposed.	Dark.
Glucose. (Plot 4' by 4' containing 5 kilogram glucose)	14.0 mgm	7.26 mgm
Molasses (Plot 4' by 4' containing 10 kilogram molasses)	8.9 mgm	3.56 mgm
Starch (Plot 4' by 4' containing 4 kilogram starch)	16.5 mgm	5.9 mgm
Ghee (clarified butter) (Plot 4' by 4' containing 2 kilograms of ghee)	11.0 mgm	4.6 mgm

It might be argued that when the soils are exposed to sunlight, the temperature of the soils is increased and this leads to an increased activity of *Azotobacter* and hence an increase in the nitrogen fixation. Experiment were carried out at various temperatures and the following table shows the fixation of nitrogen per gram of carbon oxidised at various temperatures as well as in sunlight.

TABLE

Summary of results obtained at different temperatures.

Temp.	Maximum number of <i>Azotobacter</i>	N fixed	Temp.	Maximum number of <i>azotobacter</i>	N fixed in mgms.
42° (Exposed)	22.5	13.1 mg	40° (Dark)	98.0	3.97
10-12° (Dark)	6.0	Nil	45° "	78.0	3.30
25° "	126.0	4.8	50° "	7.5	1.6
30° "	175.0	6.4	60° "	Nil	Nil
35° "	200.0	7.76			

From the foregoing results it is clear that the optimum temperature for nitrogen fixation in the dark is 35° as against about 25° ($26^{\circ}-30^{\circ}$) observed in temperate countries. The nitrogen fixed in the exposed soil, the temperature of which varied from 40° to 44° , is much greater than that in the incubated soils. The above results definitely prove that the increase of temperature in sunlight is not at all the factor responsible for the greater nitrogen fixation observed, which is mainly due to the utilisation of solar energy for nitrogen fixation.

These results have been recently corroborated by experiments carried on in the Chemical Laboratory of the Dacca University and at the Department of Agriculture of Brisbane by Dr. Kerr.

Recently experiments were performed with oxides of metals like silica, zinc oxide, ferric oxide, and aluminium oxide by mixing separately with glucose, and one set was exposed to sunlight and the other corresponding set covered with black cloth. The following results indicate that just as with soil, nitrogen fixation is possible with surfaces like the metallic oxides used, which behave as active surfaces. In these cases also the nitrogen fixation is always greater in the exposed oxides than in the covered ones although the total bacterial numbers are greater in the latter than in the former.

The following results were obtained:—

Experiments were started on 12-9-38 and analysed on 10-11-38.

Substance	Sunlight	Total carbon %	Dark	Total carbon %
	Total nitrogen %		Total nitrogen %	
Silica	0.0172%	0.2946%	0.0054%	0.5928%
Zinc Oxide	0.0152	0.0268	0.0054	0.5312

More experiments were started on December 9, 1938 and the materials analysed on January 10, 1939.

Substance	Exposed				Dark		
	Original total nitrogen	Total nitrogen	Total carbon	Total bacteria in millions per gram of sub- stance	Total N	Total C	Total bacteria in millions per gram of sub- stance
Zinc oxide	0%	0.011%	0.0268%	0.16	0.0038%	0.6172%	0.98
Aluminium oxide	0	0.0084	0.4150	0.46	0.0044	0.5824	1.98
Silica	0.016	0.028	0.3304	1.08	0.0212	0.5088	3.26
Ferric oxide	0.024	0.0336	0.4150	0.92	0.028	0.5624	2.94

Controls analysed on January 11, 1939.

Substance	Exposed	Dark
Zinc oxide	Nil	Nil
Aluminium	"	"
Silica	0.0136	0.9144
Ferric oxide	0.0208	0.0224

Experiments were carried on with soils, silica and zinc oxide under perfectly sterile conditions in 500 c.c. quartz flasks. Some experiments with sterile soils in one litre pyrex flasks were also done.

The following are the results obtained :—

In the case of sterile soils the experiments were started on September 1st, 1938. Soils in quartz flasks were analysed on March 1, 1939

Analysis of the Original Soil :—T.N.—0.0424% T.C —0.4305%.

Substance	Sunlight		Dark	
	Total nitrogen Total N	0.0424% Total C	Total carbon Total N	0.4305% Total C
Inulin ...	0.0464%	0.7732%	0.0424%	0.9924%
Arabinose ...	0.0448	0.7904	0.0424	0.9826
Fructose ...	0.0464	0.7635	0.0432	0.9786
Lactose ...	0.0456	0.7816	0.0424	0.9924
Glucose ...	0.0456	0.7635	0.0432	0.9562
Mannitol ...	0.0456	0.7732	0.0424	0.9826
Glycerol ...	0.0448	0.8048	0.0424	0.8968
Galactose ...	0.0456	0.7732	0.0424	1.0056
Maltose ...	0.0464	0.7735	0.0424	1.1026
Dextrin ...	0.0464	0.7732	0.0432	0.9826
Starch ...	0.0448	0.9364	0.0416	0.4208
Control ...	0.0408	0.3986	0.0416	0.4208

Soils in pyrex flasks were analysed on March 27, 1939.

Substance	Exposed		Dark	
	Total N	Total C	Total N	Total C
Inulin ...	0.0456%	0.8968%	0.0424%	1.1264%
Arabinose ...	0.0448	0.9086	0.0424	1.0086
Fructose ...	0.0448	0.9156	0.0432	0.9924
Glucose ...	0.0448	0.8892	0.0424	0.9638
Starch ...	0.0432	1.1026	0.0424	1.1284
Control ...	0.0416	0.4208	0.0416	0.4208

Experiments with sterile silica and zinc oxide were started on January 6, 1939

Materials used were absolutely free from nitrogen.

Substance		Exposed		Dark	
		Analysed on May 6, 1939		Analysed on June 13, 1939	
		Total nitrogen	Total carbon	Total nitrogen	Total carbon
Silica	...	0.0082%	0.4972%	0.0038%	0.6172%
Zinc oxide	...	0.0060	0.3882	0.0038	0.5892

In the controls no nitrogen fixation was observed.

From the results recorded above it is clear that appreciable fixation of nitrogen takes place when energy materials and sterile soils are exposed to sunlight under perfectly sterile conditions. Therefore it is evident that just as bacteria can fix atmospheric nitrogen, light in the complete absence of bacteria can fix atmospheric nitrogen by the help of the energy liberated as a result of the photo-oxidation of the energy materials.

It may be argued that the fixation of nitrogen can also take place in sterile soils because of the enzymes left when the soil is sterilised. But the results showing appreciable amounts of nitrogen fixation with silica and zinc oxide under completely sterile conditions dispose of the enzyme view, because no bacteria are associated with pure chemicals like silica and zinc oxide. Moreover if nitrogen fixation were to be an enzymatic reaction there should have been the same amount of fixation in the dark as in light, but it is not so. Again we have to remember the fact that under the conditions the soils were sterilised, the enzymes if any, will surely lose their activity.

Hence all the results recorded above indicate definitely that sunlight plays an important part in the fixation of atmospheric nitrogen in tropical soils.

AKALI LAND AND ITS RECLAMATION

The deficiency of the Indian Soil in nitrogen has been recognised for long, but the treatment usually prescribed is the use of expensive patent tonics like ammonium salts and other nitrogen compounds. India is a poor country and cannot afford to

use such costly chemical fertilizers on her soil. Moreover, the occurrence of alkaline patches, which have spread like a malignant tumour throughout the whole country has made the problem of reclamation really pressing. This alkaline (*usar*) land exists to the extent of nearly 5 million acres in the United Provinces alone and there is reason to believe that it is increasing.

During our researches on the study of nitrogen fixation in soils on the application of energy-rich materials, we were able to investigate the problem of *usar* reclamation with considerable success. First we investigated the main defects of the *usar* soil and found the following to be more prominent :

- (a) These soils are highly alkaline, *i.e.*, they contain an excess of sodium carbonate
- (b) The amount of available calcium, which is an important nutrient of plant-life, is exceedingly small.
- (c) These soils are highly impermeable to water and so very difficult to plough.
- (d) The nitrogen content of such soils is very small (*i.e.*, varies from 0.006% to 0.03%)
- (e) Organic matter in such soils is very small.
- (f) Deficient in bacterial activity.

A mixture of molasses and press-mud, in amounts varying with the degree of alkalinity, has been found to remove all these defects quickly as well as, we have reasons to believe, permanently. Molasses and press-mud are very cheap and provide an efficient material for permanent reclamation. By using a mixture of these substances not only is the alkalinity of the soil destroyed but also there is an increase in available calcium and total nitrogen. Moreover, the soil becomes soft and permeable. The soil nitrogen is also conserved for a long time due to the presence of carbohydrates in molasses, and the organic matter present also helps to retain the soil nutrients from being washed away during rains. The moisture retention capacity of the soil is also increased.

The underlying theory is quite simple. Nitrogen is added by fixation, which is brought about mostly by photochemical action and perhaps to some extent by bacterial activity too. Our experiments on the study of nitrogen fixation in sterile soils as well as in presence of sterile oxide due to the oxidation of energy rich materials have proved beyond doubt that photochemical fixation is very prominent in tropical sunlight. The acids present in molasses tend to neutralise the alkalinity of *usar* soils and the calcium present in press-mud increases the content of available calcium,

Our field experiments at Soraon and Saidabad near Allahabad have been very promising. The following data on the *usar* soils of these two places speak for themselves :—

Soraon			Saidabad		
A.	(1) Original pH	10.3.	A.	(1) Original pH	10.8—11.4.
	(2) pH after reclamation	7.7.		pH after reclamation ...	8.1—8.2
B.	Total Calcium as $\frac{\text{Ca O in gms}}{100 \text{ gms. soil}}$		B.	Total Calcium as $\frac{\text{Ca O in gms.}}{100 \text{ gms. soil}}$	
	(1) Original soil	1.1685 gm.		(1) Original soil	0.9012 gm.
	(2) After reclamation	1.3914 gm.		(2) After reclamation	1.2405 gm.
C.	Total Nitrogen %		C.	Total nitrogen %	
	(1) Original soil	0.0272%		(1) Original soil	0.0246
	(2) After reclamation	0.0605%		(2) After reclamation	0.0512.
D.	Total Carbon %		D.	Total Carbon %	
	(1) Original soil	0.2986%		(1) Original soil	0.2615 %
	(2) After reclamation	0.7147%		(3) After reclamation	0.8212 %
E.	Yield		E.	Yield	
		md. sr. ch.			md. sr. ch.
	(1) Rice in control/acre	0 11 8		(1) Rice control/acre	0 4 0
	(2) Rice in treated plots/acre	7 15 0		(2) Rice treated/acre	0 5 2
	(3) Barley in control/acre	0 6 0		(3) Barley control/acre	0 4 6
	(4) Barley in treated plots/acre	3 6 0		(4) Barley treated/acre	0 1 8

The reclaiming power of molasses and press-mud is very much quicker than that of the chemical reagents (*e.g.* gypsum, powdered sulphur etc.) used in western countries. Moreover, the reclamation appears to be permanent, as the fields reclaimed in previous years have continued to give practically the same yield this year too, without any renewal of molasses and press-mud. The technique of reclamation is also very simple and is easily picked up by the illiterate Indian peasant.

Molasses and press-mud are mixed with water and spread uniformly over the fields to be reclaimed. When the soil becomes soft, it is tilled and watered. The tilling is continued for about five or six weeks after which the soil is fit for sowing the crop. Care must be, however, taken to see that the water is retained in the fields by means of suitable embankments ("*bundhs*"). The field operations with these

manures are exactly the same as in ordinary cultivation and no special precaution is necessary except that a time interval of about four to six weeks is necessary between the addition of molasses and press-mud and the sowing of crops.

Our Experiments have been repeated by workers in other parts of India, and the Mysore and Bihar governments have given a favourable corroboration of our results. The report of the U. P. government on this method is highly satisfactory. There are vast tracts of alkaline unfertile lands in India and irrigation practices may be increasing their area. The economic reclamation of these lands is one of our country's greatest agricultural problems. If we can find out the solution in the utilisation of the waste products of our sugar factories, is there anything cheaper than that? The maxim of sound economic planning is "use the waste."

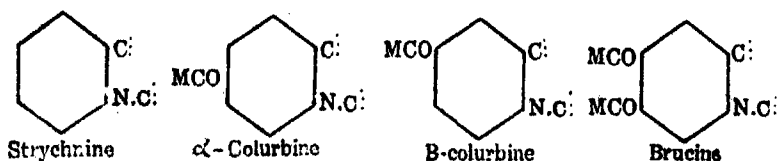
THE NATURE OF DEGRADATION OF THE STRYCHNINE MOLECULE

BY RAFAT HUSAIN SIDDIQUI, M.Sc., Ph.D. (Alig.), D. Phil. (Oxon).

MUSLIM UNIVERSITY, ALIGARH

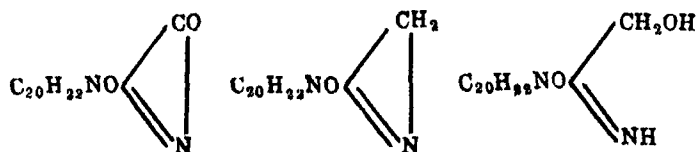
The chemistry of Strychnos alkaloids dates from the isolation of strychnine by Pelletier and Caventou in 1817, followed by the discovery of brucine two years later. The composition of the alkaloids was ascertained by Regnault in 1838, and Hanssen showed their close relationship is that oxidation with chromic acid converted both alkaloids into one and the same acid. The chief properties of the two bases were recorded by Tafel in a series of six papers (1890—1902).

Since 1908, a series of 106 papers by Leuchs and his collaborators, dealing with the stepwise degradation of the strychnine and brucine molecules has greatly added to our knowledge of these alkaloids. A structure for the strychnine molecule based on the facts known at that time was proposed by Perkin and Robinson in 1910; a subsequent series of forty-one papers by these workers and their co-workers constituted an important contribution to the subject and strychnine formula underwent various modifications. Other investigators in the field include Wieland and collaborators (1929—1940) and Achmatowicz and others, who, besides contributing to the study of strychnine and brucine, have been solely responsible for the chemistry of a subsidiary alkaloid: vomicine. Warnat in 1931 isolated three more alkaloids from the mother liquors of strychnine and brucine, and named them as α - and β -colurbines and pseudostrychnine. No work has been done on these, but on the basis of alkaline degradation, the relationship of the two colurbines is shown with strychnine and brucine. The third alkaloid pseudostrychnine has been shown by Blount and Robinson to be hydroxystrychnine. Further, Kotake and co-workers and Clemo, in 1936 independently obtained tryptamine from the alkaline degradation of



strychnine, and Holmes and Robinson re-examined the action of bromine on diketonucidine in 1939, as a result of which the entire skeleton of the molecule has now been established.

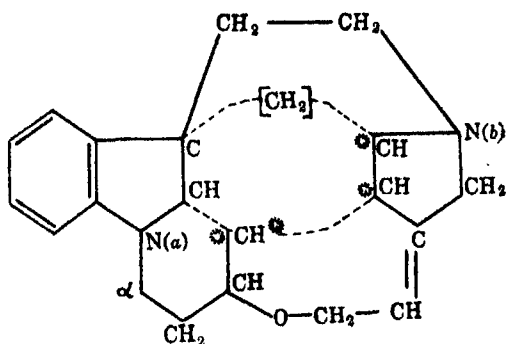
The molecule of strychnine ($C_{21}H_{22}O_2N_2$) contains two oxygen atoms, two nitrogen atoms and a double bond and is free from methyl and methoxyl groups. One nitrogen is basic in character and is designated N (*b*), while the non basic N (*a*) is included in a cyclic amide group; for, on treatment with sodium ethoxide, strychnine yields strychnic acid (an imino carboxylic acid) and, on electrolytic reduction, gives strychnidine and tetrahydrostrychnine represented by the following scheme:—



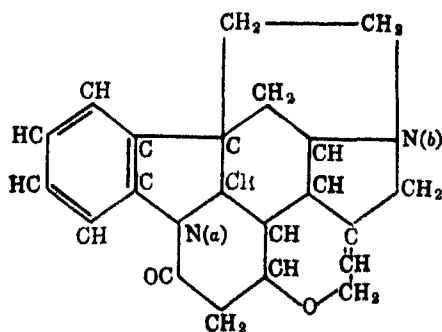
The double bond is shown by catalytic reduction of strychnine and its derivatives. One oxygen atom is included in the cyclic amide group, while the other is neutral in character as shown by the behaviour of dihydro-strychnidines and the oxygen free bases obtained in the Emde degradation and by the conversion of strychnine into iso-strychnine under the influence of basic catalysts. This as well as the formation of glycollic acid from strychninolic acid not only prove the ether function, but also its cyclic nature, and position in the strychnine molecule as shown by the grouping: N (*a*). CO.CH₂.CH.O.C.: The group N (*a*). CO.CH₂ is further shown by the formation of benzylidene and isonitroso derivatives and benzene ring attached to N (*a*). CO. with an unsubstituted position para to N (*a*) is indicated by the formation of picric acid, 3 : 5 dinitrobenzoic acid as a result of oxidation with nitric acid and of the isolation of N-oxalyl anthranilic acid by Spath in the alkaline degradation of strychnine. Strychnine and brucine which is a dimethoxy derivative of the former contain the grouping as shown in the relationship of colurbines to strychnine and proved by the degradative products isolated by Hanssen, Leuchs and Wieland. The degradative studies of the alkaloid and its derivatives have been carried out by means of chromic acid, bromine, nitric acid alkali, cyanogen bromide, potassium permanganate, perbenzoic acid and by Hofmann and Emde methods.

Chromic acid, on oxidation followed by electrolytic reduction, gave diketonuclidine, a substance which is free from aromatic benzene nucleus, while nitric acid gave dinitrostrychnic acid, dinitrostrychol carboxylic acid and other simple products which have been synthetically confirmed by Hill and Robinson. Action of cyanogen bromide has not been studied very exhaustively; the treatment of strychnine with barium hydroxide converts it into an isomer and fusion of the alkaloid with alkali has resulted in the isolation of pyridine, quinoline, carbazole, indole, ethyl indole,

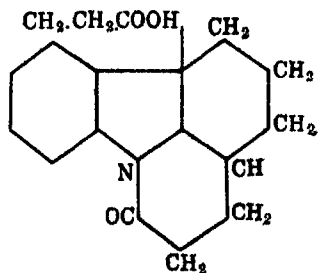
tryptamine and other products. The isolation of tryptamine has an important bearing on the subject, and although it gives no conclusive information about the attachment of the C_2H_4 group to the α - or β - carbon atom of the indole nucleus, it has fixed the position of the basic nitrogen with regard to the other. Oxidation with potassium permanganate has further fixed the group N (b). CH_2 , in the molecule of strychnine as on oxidation it gives N (b). CO_2 , while the studies on strychninolones has shown the grouping N (a). CO . $CH:CH$. $CH \begin{smallmatrix} C \\ \diagup \diagdown \\ C \end{smallmatrix}$: Hofmann and Emde degradations gave rise to various isomers, and similarly, the action of sulphuric acid



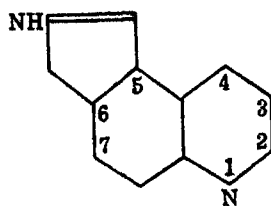
(I)



(II)



(III)



(IV)

produced various isomeric sulphonic acids in which the group N (a). $CO.CH_3$ is involved besides the aromatic nucleus. The Emde degradation further showed the group $C:C.C$. N (b) in strychnine. A very important observation in this connexion is obtained by the re-examination of the action of bromine on diketonucidine, which proved the attachment of the C_2H_4 group to the β - position of the indole nucleus.

The above fragments on combination give rise to the above formula (I) in which the group $\text{CH.OH}\ddagger$ is required in order to accommodate the isomeric strychninolones and the degradation of brucine to eurbine, while the group CH.OH^* in the pyrrolidine ring N (*b*) is required for the explanation of the formation of methoxymethyl-chano-dihydroneostrychnone on oxidation with perbenzoic acid. If in formula (I) all the dotted positions are linked up, then it would give rise to the representation (II) proposed by Professor Sir Roberts Robinson, Kt., D Sc., LL.D., F.R.S. (Oxford), and which is now accepted for the strychnine molecule. So far as the synthetic studies are concerned, Openshaw and Robinson have, in 1937, synthesized the substance represented by formula (III) and Wieland in 1938, has obtained 5:6 pyroquinoline as shown by formula (IV) besides the syntheses of the simpler degradation products mentioned above.

APPENDIX V

SUMMARIES OF PAPERS COMMUNICATED (SECTIONS A AND B)

SECTION A

THE IMPORTANCE OF THE PRIMARY ABSORPTION PROCESS IN PHOTO-CHEMICAL REACTIONS. II.

By A. K. Bhattacharya and Ratan Singh, Chemistry Department, Allahabad University.

In part I (Communicated by the senior author) it was emphasized that the method of studying photo-chemical reactions involving solutions in stages (primary and secondary) would help a good deal in explaining some of the most controversial problems regarding temperature coefficient and quantum yield of photo-chemical reactions.

We have studied in detail the influence of the primary absorption process with the reactions between (1) potassium oxalate and iodine, (2) tartaric acid and bromine, (3) sodium nitrite and iodine, (4) ferrus sulphate and iodine and (5) ammonium oxalate and mercuric chloride in sunlight and also in thousand watt lamp with or without light filters and at different temperatures. The quantum yield has also been noted. It has been found that if the influence of the primary absorption process alone is considered in promoting the photo-chemical reactions, then the temperature coefficient gives a value equal to unity and Einstein's law of photo-chemical equivalence is also obeyed.

AN ELECTRICAL METHOD FOR DETERMINING THE ABSORPTION COEFFICIENT OF SOUND. *By Chandra Kanta, Miss, Research Student, Physics Department, Allahabad University.*

This is a preliminary report of the method which utilizes Campbell's inductometer in measuring the electrical impedance of a Moving coil receiver Unit at different air load impedances of an air column. This air load is varied by changing the length of the air column and measuring the electrical impedance of the corresponding lengths. The air column is first backed by a perfect reflector and then by a sound-absorbing material. The difference between the two sets of readings enables one to determine the sound-absorbing coefficient. The coefficient of reflection and the phase change on reflection can also be calculated. No significant relation between reflection co-efficient and phase change has been found. The phase change in the case of porous materials made from assembling capillary tubes is found to be greater than π whereas in other substances it was less than π . The acoustic impedance of the capillary tubes as calculated from Raleigh's formula is found to be in reasonable agreement with experiment.

VISCOSITY OF SOME SOLS AT THEIR VARIOUS STAGES OF PURITY AND DILUTION. *By S. Ghosh, and S. M. Ayub, Department of Chemistry, University of Allahabad.*

It is well known that the sols that yield gels on coagulation grow viscous and may finally set to a firm gel on prolonged dialysis. Dhar and co-workers concluded that such increase in the viscosity of a sol with progressive dialysis is due to increased hydration. Banerji and Ghosh studied the

increase in the viscosity of ferric phosphate sol with increasing purity and observed that this sol developed structural flow with the continuous removal of the stabilizing electrolyte. In this paper the viscosities of sols of ferric hydroxide (prepared by the acetate method), zirconium hydroxide, stannic hydroxide and ceric hydroxide of different degrees of purity at various dilutions have been investigated at different pressures by the apparatus of Ostwald suitably modified by us to find out how the structural flow develops in these cases.

The results obtained here lead to the following important conclusions :--

(i) The increase in the viscosity of a sol on progressive dialysis is closely associated with its structural flow, which increases with the increasing purity of the sol ; (ii) the structural flow increases with the increasing concentration of the dispersed substance ; and (iii) the structural flow is dependent on the properties of the compound present in the colloidal condition.

The authors suggest, therefore, that the sols that yield either a gel or gelatinous precipitate on coagulation appear highly viscous on continued dialysis due more to the development of structural flow than to the increased hydration of colloid particles.

STRUCTURAL FLOW IN COLLOIDS. *By S. Ghosh*, Department of Chemistry, University of Allahabad.

Most of the highly viscous sols do not behave like ordinary liquids and Poiseuille's law is not applicable in their cases. The viscosity or better structural flow diminishes with the increasing rates of shear and the sols behave like plastic bodies. High viscosity of such sols has been ascribed to an orientation of colloid particles originating from a 'loose crystallographic force', which is sufficiently labile due to high-hydration of the colloid particles. The force for the growth on the surface of a colloidal particle in the case of some sols increases the tendency of association of liquid molecules on its surface, which leads to high solvation and checks the aggregation of colloid particles. Disturbances created by shaking or stirring either increase or decrease the structural flow. The phenomenon of 'thixotropy' in the sol-gel transformation can be explained on these views.

The failure of the highly viscous sols to obey Einstein's viscosity-concentration relationship is due to such orientation of colloid particles, which imparts a rigidity to the sol. In general, the experimental results show that the structural flow of a sol increases with the decrease in the electrical charge on the colloid particles and the electroviscous effect of Smoluchowski is more than counter-balanced by this effect.

Colloids can be profitably grouped in two classes, *vis.*, reversible and irreversible without ascribing much importance to the hydration of the colloid particles. To the reversible class belongs the sols of some organic substances, *e.g.*, gelatine, agar, starch, tannins, dye-stuffs, etc., and inorganic substances like silicic, vanadic, tungstic, molybdic acids, etc. The reversibility of sols depends upon the tendency of dissolution of their colloidal particles to associated or simple molecules in solution.

FORMATION OF PERIODIC PRECIPITATE IN THE ABSENCE OF A FOREIGN GEL. *By R. N. Mitra*,
(Communicated by Dr. S. Ghosh)

The formation of periodic precipitates by the interaction of two reacting solutes in gel medium was reported by R. E. Liesegang in 1896. Numerous similar observations were subsequently made by Ostwald, Bradford, Dhar and Chatterji, Hedges and Henley and others. In the production of periodicities by such double decomposition method in gel medium, there are three stages guiding the phenomenon : (1) formation of an insoluble substance by the chemical interaction between two

reacting solutes; (2) aggregation of the insoluble substance to form colloidal aggregates, and finally, (3) the precipitation of the colloidal material in periodic manner.

In a simple process like the one adopted by the author to obtain periodic precipitates, the first stage of the process has been completely eliminated. No preceding chemical interaction is necessary for the production of the insoluble substances, which already exists in colloidal condition in the absence of any gel. The sols, of partially lyophilic nature, of ferric hydroxide (prepared by acetate and carbonate methods), ferric phosphate, ferric arsenate, ferric borate, ceric hydroxide, chromic hydroxide, chromic arsenate and stannic hydroxide give rise to periodicities in their coagula when they are subjected to slow coagulation by the addition of mono or bivalent coagulating ions according to their respective nature and purity.

In elucidating the mechanism of the process it has been observed that there are two factors guiding the phenomenon, (1) a sol must be purified to such an extent that it leaves sufficient range for slow coagulation, the coagulation velocity curve being S-shaped; (2) the coagulum containing 0.000295 g. atom of the metal constituting the sol must occupy a compact volume of 10 c.c. on centrifuging for 5 minutes at revolutions of 2,000 r. p.m. When a sol which satisfies the above two conditions is subjected to slow coagulation, the coagula which appear in stages have the facility for coexisting with the uncoagulated sol and form adsorption centres where the first set of nuclei start. With time the adsorption centres get thickened up by adsorbing more sol, and form uniform ring-shaped bands. The optimum volume of the coagulum which settles periodically, is 0.5 c.c. when the coagulum from 9 c.c. of the total volume of 20 c.c. of the sol-electrolyte mixture is centrifuged for 5 minutes at a revolution of 2000 r. p.m.

With increase in the purity of sol, the coagulum gets more hydrated and the range for slow coagulation decreases with the result that the above-mentioned two conditions are not satisfied and no good rings appear, though the adsorption of the sol by its own coagulum increases.

THERMAL IONIZATION OF STRONTIUM. *By B. N. Srivastava*, Lecturer in Physics, Allahabad University.

In this paper the thermal ionization of strontium vapour has been experimentally investigated by an apparatus already described by the author elsewhere in his work on barium. Experiments have been carried out at various temperatures and pressures of strontium vapour and the equilibrium concentrations of Sr and electrons inside the furnace have been obtained by allowing them to effuse out through a narrow opening. From these the equilibrium constant and the energy of ionization have been calculated. The results obtained agree, within the limits of experimental error, with the theory of thermal ionization and the known spectroscopic value of the ionization potential of Sr.

ADSORPTION OF CATIONS BY A CRYSTALLINE VARIETY OF ALUMINIUM SILICATE. *By S. P. Srivastava*, Chemistry Department, University of Allahabad (Communicated by Dr. S. Ghosh.)

It is generally believed that the properties of soil are controlled to a great extent by the inorganic and organic colloids present in the soil, and that the inorganic colloidal material of the soil is essentially the same as the artificial gels of silica, ferric oxide and alumina. Recently, Mattson and others have attempted to prove this by measuring the adsorption of cations and anions by the mixing of freshly precipitated alumina, silica and ferric oxide.

In this paper an attempt has been made to measure the adsorption of different cations by the freshly prepared insoluble aluminium silicate obtained by the interaction of aluminium chloride and

Sodium Silicate solutions in equivalent proportions. The aluminium silicate thus obtained was purified as far as possible from the electrolytes obtained as the byproduct. The silicate was of crystalline variety and adsorption experiments were carried out with this silicate for different cations.

The results obtained show that there is considerable adsorption of the cations producing acidity of the solution : these can be arranged in the following decreasing order :

$\text{Na} > \text{Mg} > \text{Ca} > \text{K}$, when the adsorption is expressed in milli-atoms per gram of the solid.

It has been of interest to note that the adsorption of these cations is also exchangeable. The exchange of adsorbed calcium by a solution of sodium chloride was investigated and has been found to be practically complete for a concentrated solution of NaCl.

SOME COLLOIDAL BEHAVIOUR OF USAR SOILS TREATED WITH MOLASSES. *By S. P. Srivastava*,
Chemistry Department, University of Allahabad, (Communicated by Dr. S. Ghosh.)

In a number of publications, Dhar has emphasized the use of molasses as a reclaiming agent for alkaline or usar soils. Such colloidal properties of usar soils as the exchange of calcium and the general structure of the soil grains have been studied by the different amounts of molasses added to usar soils.

The results obtained in this paper show that the exchangeable calcium, which is ordinarily very small in usar soils, considerably increases by the treatment of molasses. It increases with increasing amount of molasses and also with increasing time of treatment. It has also been observed that in usar soils, though the organic colloidal material is too small, the grains of the soil (mainly clay) takes considerably long time for settling showing that the grains are of very small size. The treatment of molasses to usar soils remarkably improve the settling of the soil and the latter becomes practically similar to a good sample of garden soil.

The action of molasses in improving the usar soils to the condition of good garden soil is mostly due to the changes in hydrogen ion concentration of soil produced by the organic acids present in molasses. It is obvious that the acidity of molasses would also considerably increase—if it is exposed to light and air for longer periods—due to photo-oxidation of carbohydrates in molasses to various organic acids.

INVESTIGATIONS ON ALUMINIUM SILICATE SOLS. I. *By S. P. Srivastava, and S. Ghosh*,
Chemistry Department, University of Allahabad.

It is well-known that the colloidal character of clays plays an important role in the mechanism of the varying colloidal behaviour observed in soils. As aluminium oxide and silicic acid are the main components of clay, a systematic investigation of the colloidal behaviour of the aluminium silicate sols has been undertaken with a view to find out how far the colloidal behaviour changes with the composition of the silicate.

In this paper some preliminary experiments on the preparation of aluminium silicate sols containing aluminium oxide and silicic acid in different proportions have been described. The sols of different compositions can be obtained by the interaction of aluminium chloride and sodium silicate solutions at different acidities controlled by the addition of a solution of sodium acetate. The authors have been able to obtain sols of different compositions of aluminium silicate in very concentrated condition. The concentration of the sols prepared in different samples contained 60–70 gr. of

total solid per litre The sols are found to be highly viscous and obtained by continued hot dialysis; they quickly yield transparent gel on treatment with suitable coagulating electrolytes.

CHEMICAL EXAMINATION OF THE LEAVES OF LANTANA CAMARA-LINN. COMPOSITION OF THE ESSENTIAL OIL. *By Jagatnarayan Tayal and Sikhibhusan Dutt.*

Lantana Camara—Linn, known as Ghaneri in Hindustani, is a native of America, but grows in wild state also in many parts of India. The leaves are very highly medicinal; after boiling with barley they are given to women after delivery. They are also often used against indigestion. The essential oil of leaves of the Indian variety was never systematically examined. Of course Moudgill and Vridhachalam did some work on the south Indian Variety in which they identified Phellandrene and tentatively showed the presence of Caryophyllene. Consequently, the investigation was undertaken by the present authors.

The leaves which are very fragrant, were locally collected and steam-distilled in a big copper-distilling apparatus. The essential oil obtained was yellowish brown with a very pleasant odour. On thorough chemical examination, it yielded the following constituents :—

1. Phellandrene	...	...	...	40.6%
2. Dipentene	...	...	...	20.7%
3. Linalool	..	...	...	5.1%
4. Geraniol	...	...	...	7.3%
5. Citronellol	...	...	..	2.4%
6. Unidentified aldehyde	...	...	...	1.7%
7. Caryophyllene	...	...	...	16.7%
8. Sesquiterpenes (Unidentified) ...	...	...	...	4.3%

THE DETERMINATION OF SOIL CONSTANTS AT BROADCAST AND ULTRA HIGH FREQUENCIES. *By B. D. Toshniwal and G. R. Toshniwal.*

The conductivity of soil with different moisture contents has been measured for frequencies lying between 1,500 kc./sec. and 550 kc./sec. The differential transformer method has been found to be extremely useful for the purpose. The conductivity was found to vary from 59×10^{-12} e.m.u. for 88% moisture to 106×10^{-12} e.m.u. for 30.4% moisture. The conductivity was also determined for 423 Mc/sec. by the lecher wire method and was found to be 5—6 times the conductivity at broadcast frequencies.

SECTION B

THE CYTOPLASMIC INCLUSIONS IN THE OOGENESIS OF RHIPICEPHALUS SANGUINEUS (LATREILLE). *By Ram Saran Das, Zoology Department, University of Allahabad.*

1. The Golgi bodies are in the form of platelets and dictyosomes.
2. No fatty droplets or fatty yolk bodies are present
3. Mitochondria are observed supravitaly without the use of any dye.
4. Albuminous yolk are produced by the direct transformation of mitochondria. Some may also arise independently in the ground cytoplasm.

5. The swollen bodies of too big a size to be considered mitochondria stain with Janus green B. They are considered swollen mitochondria transforming into albuminous yolk. The definitive albuminous yolk spheres do not stain with Janus green B.
6. Nucleolar extrusion is not observed.
7. The nucleolus is consistently oxyphil and gets highly vacuolated.
8. There are no bodies corresponding to Parat's vacuome in the oocyte of this animal. Neutral red stains the mitochondria to a certain extent
9. The cells of the germinal epithelium intimately associated with the oocytes are not considered homologous with the "nurse-cells" of insects

CHLOROPHYLL AND CARBOHYDRATE CONTENTS OF TRITICUM VULGARE IN RELATION TO MANURES. *By Gopi Narain Dikshit, and S. Ranjan.*

The quantities of all the four pigments (Chlorophyll α , Chlorophyll β , Carotin and Xanthophyll) show wide fluctuations during the ontogenic drift of the wheat plant. These fluctuations are noticed in plants growing in the sub-soil, molasses, compost and control beds.

The quantity of monosaccharides was the greatest in the young stage and rapidly declined as the age of plants advanced. The di-sugars, however, show a maximum concentration when the life-cycle of the plant is half completed.

There is no definite correlation between the plant pigments and the soluble carbohydrates. This proves that the pigments under the given experimental conditions are above the limiting value.

STUDIES ON THE SEXUAL CYCLE OF THE LIZARD *H. FLAVIVIRIDIS* (RUPPEL). *By S. K. Dutta*, Zoology Department, University of Allahabad.

The paper deals with the seasonal variations in the gonads and in the genital ducts of the lizard *H. flaviviridis*. The occurrence of a corpus luteum in the ovary of the lizard is recorded and the structure is described in detail.

CYTOLOGICAL STUDIES IN CAJANUS. THE SOMATIC CHROMOSOMES AND THE PRO-CHROMOSOMES. *By Naithani, S. P.* (Communicated by Dr. R. K. Saksena.)

The present investigation deals with the study of Somatic Chromosomes and the pro-chromosomes in *Cajanus*.

The seeds of different varieties were obtained from Pusa and Cawnpore and some were secured locally from the market.

The Somatic Chromosomes were studied from root-tips, which were fixed mostly in Maeda's modification of Nawashin's fluid.

The most desirable time to fix the root-tip was found to be between 10 and 12 P.M. In all the types studied, the diploid number of Chromosomes is twenty-two. No morphological differences is noticed between the Chromosomes of the different varieties. The chromosomes however differ among themselves, some being slightly curved and others V and J-shaped. Two of the chromosomes bear small Satellites. Somatic pairing of Chromosomes is exhibited in the various types.

At the resting stage the chromosomes, instead of forming portions of reticulum, remain condensed and highly Chromatic demonstrating conspicuous pro-chromosomes. A careful account of

these chromatic bodies showed that their number is twenty-two. There is thus a precise correspondence between the pro-chromosomes and the number of chromosomes at metaphase.

LEPTOTENE THREAD. CHROMOMERE OR CHROMONEMIC. *By Naithani, S. P.* (Communicated by Dr. R. K. Saksena)

A photo-micrographic evidence is provided to show that the leptotene and Zygotene threads are Chromonemic and that the so-called Chromomers are the optical images of the twist of the finely coiled spirals. The causes of the spirilization are discussed.

SYNTHESIS OF GROWTH-PROMOTING SUBSTANCES BY SOME SPECIES OF THE GENUS *PYTHIUM*.
By R. K. Saksena, Department of Botany, University of Allahabad.

1. The nutrient solution used containing mineral salts and pure dextrose does not contain any appreciable amount of growth-promoting substances.

2. *Pythium arrhenomanes*, *P. deliense*, *P. graminicolum*, *P. hyphalosticton* and *P. mamillatum* are capable of unlimited growth in the nutrient solution.

3. The results of the experiments show that the organisms are capable of synthesizing their own growth-promoting substances from the simple ingredients of the nutrient solution.

4. Such growth-promoting substances manufactured by the organisms are also given off by the mycelium into the solution.

5. The addition of thiamin to the nutrient solution has no marked effect on the growth of these organisms.

6. The failure of *Pythium arrhenomanes* and *P. hyphalosticton* to grow in the synthetic liquid medium used by Robbins and Kavanagh is found to be due to the concentration of the medium. It is suggested that the concentration hinders the synthesis of growth-promoting substances and thus affects the growth.

IMPORTANCE OF GROWTH-PROMOTING SUBSTANCES IN THE METABOLISM OF *PYTHIUM INDIGIFERA* BUTLER. *By R. K. Saksena*, Botany Department, University of Allahabad.

1. *Pythium indigoferas* does not grow on a synthetic medium in which the source of nitrogen is not peptone.

2. It does not require a complex nitrogenous molecule as such, as shown by the fact that it grows on a medium in which peptone is completely hydrolysed to its constituent amino-acids.

3. While there is good growth on peptone and hydrolysed peptone there is no growth on a mixture of amino-acids which is representative, as far as possible, of the hydrolytic products of a complete protein.

4. The addition of thiamin to the synthetic medium, in which the source of nitrogen is ammonium nitrate, does not induce growth.

5. The fungus is capable of growing in butter-milk, but the utilization of casein of butter-milk is conditional on the presence of a growth-promoting substance, which is easily separable from the milk by alcoholic precipitation.

6. The organism can grow on a synthetic medium, in which the source of nitrogen is ammonium nitrate, when casein extract or lentil extract or yeast is added to the medium.

7. The results of the experiments clearly show that the organism does not respond to thiamin, but requires a complex of growth-promoting substances for its growth.

SOME OBSERVATIONS ON THE CYTOLOGY OF *SAPROLEGNIA DELICA*, COKER. *By R. K. Saksena and K. S. Bhargava.*

1. An account of cytological studies of the vegetative mycelium and the development of zoosporangia and zoospores of *Saprolegnia delica*, Coker is given.

2. Observations on the living material were made both with and without vital staining. Even when no stain was used, fat particles, filamentous mitochondria, vacuoles, nuclei, pre-existing corpuscles, and sphaero-crystals were observed in the hyphae. With the help of vacuolar dyes the origin and evolution of vacuolar system was studied. Of all the dyes neutral red proved to be the least toxic. Sphaero-crystals became more distinct with neutral red. No metachromatic corpuscles were found in the hyphae. With Janus green Hcht B and dahlia violet, filamentous mitochondria became more distinct and were also seen in the process of fragmentation and vesiculation. Janus green, which was less toxic than dahlia violet, formed a reduction product by the activity of cytoplasm.

3. The mycelium was fixed in a number of nuclear and mitochondrial fixatives. For the fixation of the mitochondria Helly's liquid and for the nuclei Flemming's weak solution modified by Saksena proved most satisfactory. In fixed preparations the structure of the mitochondria was similar to that observed in the living condition. The main portion of the nucleus was seen to consist of a central body, which takes a dark stain with iron-alum haematoxylin. Surrounding this was a layer of nucleo-hyaloplasm, which was bounded externally by a distinct nuclear membrane. No mitotic division was observed.

4. The mitochondrial and the vacuolar systems, the nuclei and the development of the zoosporangia and the zoospores were studied both in the living and the fixed material.

5. Of all the mitochondrial fixatives used, corrosive sublimate-formal gave the best preparations. With iron-alum haematoxylin mitochondria were stained black and were seen as long filamentous bodies. For the fixation of nuclei Bouin's fluid and Flemming's weak solution modified by Saksena gave good results. No nuclear division was observed within the zoosporangium.

6. In the fixed preparations of the motile zoospores, which bore 2 cilia, a single nucleus lying towards the pointed end was observed. In their resting stage it appeared shifted towards the centre. In the germinating zoospores several nuclei were seen distinctly in the germ tube.

7. With the Golgian technique the so-called 'Golgi bodies' found in animal cells were not observed. Mitochondria, nuclei and the vacuolar contents, however, became black.

A PHYSIOLOGICAL STUDY OF *SAPROLEGNIA DELICA*, COKER. *By R. K. Saksena and K. S. Bhargava.*

1. *Saprolegnia delica* is capable of unlimited growth in a nutrient medium, containing mineral salts and pure dextrose, which does not contain any significant amount of growth-promoting substances. The results of the experiments show that the organisms are capable of synthesizing their own growth-promoting substances from the simple ingredients of the nutrient solution. Such

growth-promoting substances manufactured by the organism are also given off by the mycelium into the solution.

2. Addition of vitamin B₁ (Thiamin) to the nutrient solution has no marked effect on the growth of the fungus.

3. The fungus is capable of utilizing sulphur from cystine and not from sulphates. The minimum quantity of cystine required for the growth of the fungus in the nutrient medium is 0.0005 gm. per litre.

4. Of the 15 carbohydrates and 5 alcohols tested as source of carbon for the fungus, only glucose, levulose, maltose, dextrin, glycogen, and soluble starch are utilized and are most favourable for the growth and acidification of the media. Arabinose, galactose, mannose, rhamnose, xylose, lactose, sucrose, raffinose, inulin, glycerine, erythrite, mannite, dulcitol, and sorbitol are not assimilated. The fact that it can utilize maltose starch and glycogen shows that it secretes the enzymes maltase, diastase and glycogenase.

5. Of the 17 nitrogenous substances tested as source of carbon, only alanine, asparagine, aspartic acid, bacto-peptone, cystine, glutamic acid, histidine, and leucine are utilized.

6. The fungus is capable of utilizing nitrogen from alanine, ammonium nitrate, asparagine, aspartic acid, glutamic acid, histidine, tyrosine, valine, and, to a less extent, from leucine and acetamide. Cystine and Cystine-hydrochloride are poor sources of nitrogen supply.

7. The fungus fails to grow in nutrient solutions where phosphate is absent. The minimum amount of K_2HPO_4 required for the growth of the fungus is 0.0001 gm. per litre.

8. The fungus is capable of hydrolysing peptone. Ammonification accompanies the reaction.

9. The fungus cannot hydrolyse fats.

10. The minimum, optimum, and maximum temperatures for the growth of the fungus are 4°C, 20°C—27°C, and 32°C, respectively.

11. The most favourable temperature for the formation of sexual organs is 15°—21°C, while every high and low temperatures inhibit their formation. Hydrogen-ion concentration of the medium ranging from 4.0 to 7.1 has no effect on their formation.

12. Of the various media tested for the formation of sexual organs, 0.05% haemoglobin solution in water was found to be most useful.

INFLUENCE OF RADIATION ON THE RATE OF RESPIRATION OF SOME COLOURED FLOWERS. By Shri Ranjan and Brij Behari Lal Saksena.

The plant materials used in this work were the flowers of Bougainvillea (red), Nerium (yellow and red), and Canna (yellow). Osram half watt lamp of 1500 C.P. was used as source of light, throughout the experiment, at a distance of 16".

The respiration rate in light, in the case of the Canna flowers was the same as that in darkness.

The respiration rates of Nerium flowers (both pink and yellow) and Bougainvillea flowers, showed an increase of respiration soon after they were exposed to light. The high rate, however, was not maintained and after 6 hours the respiration rate dropped off slightly.

APPENDIX 6

OFFICE-BEARERS AND MEMBERS OF THE COUNCIL OF THE NATIONAL ACADEMY OF SCIENCES, INDIA, FOR THE YEAR 1939

PRESIDENT

The Hon'ble Sir Shah Muhammad Sulaiman, Kt, M.A, LL.D, D.Sc., F.N.I.,
F.N.A.Sc.

VICE-PRESIDENTS

H. R. Mehra, M.Sc., Ph.D. (Cantab), F.N.I., F.N.A.Sc.
S. M. Sane, B.Sc., Ph.D., F.N.A.Sc.

HON. TREASURER

Saligram Bhargava, M.Sc., F.N.A.Sc.

GENERAL SECRETARIES

Shri Ranjan, M.Sc. (Cantab.), D.Sc., F.A.Sc., F.N.A.Sc.
D. S. Kothari, M.Sc., Ph.D. (Cantab), F.N.I., F.N.A.Sc.

FOREIGN SECRETARY

D. R. Bhattacharya, D.Sc., Ph.D., F.Z.S., F.N.I., F.N.A.Sc.

MEMBERS OF THE COUNCIL

S. B. Dutt, D.Sc. (Lond), P.R.S., D.I.C. (Lond.), F.N.I., F.N.A.Sc.
M. R. Siddiqui, M.A., Ph.D., F.N.I., F.N.A.Sc.
A. C. Banerji, M.A., M.Sc., F.R.A.S., I.E.S., F.N.I., F.N.A.Sc.
Rai Sahib P. L. Srivastava, M.A., D.Phil. (Oxon.), F.N.I., F.N.A.Sc.
Rao Bahadur B. Viswanath, F.I.C., F.N.I., F.N.A.Sc.
M. N. Saha, D.Sc., F.R.S., F.N.I., F.N.A.Sc.
K. N. Bahl, D.Sc. (Oxon), D.Phil., F.N.I., F.N.A.Sc.
J. C. Ghosh, D.Sc., F.N.I., F.N.A.Sc.
A. M. Kureishy, M.A., F.N.A.Sc. :—

The following members were elected Office-bearers and Members of the Council
of the National Academy of Sciences, India, for the year 1940 :—

PRESIDENT

The Hon'ble Sir Shah Muhammad Sulaiman, Kt, M.A., LL.D., D.Sc., F.N.I.,
F.N.A.Sc.

VICE-PRESIDENTS

H. R. Mehra, M.Sc., Ph.D., F.N.A.Sc.
S. M. Sane, B.Sc., Ph.D., F.N.A.Sc.

HON. TREASURER

Saligram Bhargava, M.Sc., F.N.A.Sc.

GENERAL SECRETARIES

Shri Ranjan, M Sc (Cantab.), D.Sc., F.A.Sc, F.N.A.Sc.

D.S. Kothari, M.Sc., Ph.D. (Cantab), F.N.I., F.N.A.Sc.

FOREIGN SECRETARY

D. R. Bhattacharya, D Sc., Ph.D., F.Z.S, F.N.I., F.N.A.Sc.

MEMBERS OF THE COUNCIL

S. B. Dutt, D Sc. (Lond.), P.R.S., D.I.C (Lond.), F.N.I., F.N.A.Sc.

Khan Bahadur Mian Afzal Husain, M Sc, M.A. (Cantab.), I.A.S, F.N.I., F.N.A.Sc.

A. C. Banerji, M.A., M.Sc., F.R.A.S., I.E.S., F.N.I., F.N.A.Sc.

Rai Sahib P. L. Srivastava, M.A., D.Phil (Oxon.), F.N.I., F.N.A.Sc.

P. K. Dey, I.A.S, F.N.A.Sc

Ram Kumar Saksena, D Sc. (Paris), F.N.A.Sc

K. N. Bahl, D.Sc. (Oxon.), D.Phil., F.N.I., F.N.A.Sc.

S. S. Bhatnagar, O.B.E., D.Sc., F.N.I., F.N.A.Sc.

A. M. Kureishy, M.A., F.N.A.Sc.

APPENDIX 7

LIST OF MEMBERS

(Arranged alphabetically)

*—Denotes a Fellow

†—Denotes a Fellow of the National Institute of Sciences of India

Date of Election		Alphabetical List of Members
31-10-35		Agarwal, Rai Amar Nath, Bari Kothi, Daraganj, Allahabad.
20-4-36	*	Ahmad, Ziauddin, Kt, D Sc., Muslim University, Aligarh.
20-4-35	† *	Ajrekar, Shripad Lakshman, B.A., I E S., 855 Bhamburda, Poona.
17-4-31	*	Asundi, R K., Ph.D., Physics Department, Benares Hindu University, Benares.
1-1-30	† *	Bahl, K N, D.Phil, D Sc, Professor of Zoology, Lucknow University, Lucknow.
1-1-30	† *	Banerji, A.C., M.A, M.Sc, F R A.S., I.E S., Professor of Mathematics, Allahabad University, Allahabad.
22-12-32	† *	Banerji, S. K, D.Sc., Meteorologist, Ganeshkhind Road, Poona 5.
20-4-36	*	Basu, N. M., D Sc., 7 Bakshi Bazar Lane, Dacca.
17-4-31	*	Basu, Saradindu, M.Sc., Meteorologist, Meteorological Office, 45 Prithviraj Road, New Delhi
31-10-35	† *	Bharadwaja, Yajnavalkya, Ph.D., Professor of Botany, Hindu University, Benares.
19-3-31	*	Bhargava, Saligram, M.Sc., Reader, Physics Department, Allahabad University, Allahabad.
17-4-31		Bhargava, Vashishta, M.Sc., I C S, Sessions and District Judge, Bulandshahr.
17-4-31		Bhatia, K. B, I C S, Sitapur.
17-12-35		Bhatia, M.L, M.Sc, Lecturer in Zoology, Lucknow University, Lucknow.
15-9-36		Bhatnagar, Birendra Kumar, B.Sc., Bank Road, Allahabad
21-4-33	† *	Bhatnagar, S. S., D Sc, O.B E, Director, Board of Scientific and Industrial Research, Commerce Department, New Delhi.

Date of
Election

Alphabetical List of Members

- 20-12-34 * Bhattacharya, A. K., D.Sc., Chemistry Department, Allahabad University, Allahabad
- 1-1-31 † * Bhattacharya, D. R., M.Sc., Ph.D., Docteur ès Sciences, Professor of Zoology, Allahabad University, Allahabad.
- 20-4-36 † * Bose, N. K., Ph.D., Mathematical Officer, Irrigation Research Institute, Lahore.
- 20-4-36 † * Burridge, W., D.M., M.A. (Oxon.), Professor of Physiology, Lucknow University, Lucknow.
- 31-10-35 Chakravarty, D. N., D.Sc., Professor of Chemistry, College of Sciences, Nagpur.
- 10-5-35 † * Champion, H. G., M.A., Sylviculturist, Imperial Forest Research Institute, Dehra Dun.
- 1-1-30 † * Chatterji, G., M.Sc., Meteorologist, Upper Air Observatory, Agra.
- 17-4-31 * Chatterji, K. P., M.Sc., A.I.C., F.C.S., Reader, Chemistry Department, Allahabad University, Allahabad.
- 10-5-37 Chatterji, N. G., D.Sc., H.B., Technological Institute, Cawnpore.
- 9-2-34 Chaturvedi, Pandit Champa Ram, Professor of Mathematics, St. John's College, Agra.
- 17-12-35 Chaudhury, K. Ahmad, M.Sc., B.A. (Cal.), D.Sc., (Edin.), Wood Technologist, Imperial Forest Research Institute, Dehra Dun.
- 25-3-39 Chaudhri, Rafi Mohammad, M.Sc., Ph.D. (Cantab), Reader in Physics, Muslim University, Aligarh.
- 10-5-37 Chaudhury, S. S., M.A., M.Sc., Kadam Kuan, P. O. Bankipore, Patna.
- 10-5-35 † * Chopra, R. N., Lt.-Col., C.I.E., M.B., I.M.S., Director, School of Tropical Medicine, Central Avenue, Calcutta.
- 31-10-35 Dabodghao, V. M., Physics Department, College of Science, Nagpur.
- 28-10-32 * Das, A. K., D.Sc., Upper Air Observatory, Agra.
- 22-12-32 * Das, B. K., D.Sc., Professor of Zoology, Osmania University, Hyderabad, Deccan.
- 19-3-31 * Das, Ramsaran, D.Sc., Zoology Department, Allahabad University, Allahabad.
- 17-12-35 * Das Gupta, S. N., M.Sc., D.I.C., Ph.D., Reader in Botany, Lucknow University, Lucknow.
- 29-7-36 Dass, A. T., Dharam, M.Sc., 13 Strachey Road, Allahabad.
- 20-4-36 † * Datta, S., D.Sc., D.I.C., Professor of Physics, Presidency College, Calcutta.

Date of
Elec tion

Alphabetical List of Members

- 15-9-37 Dayal, Jagdishwari, M.Sc., Zoology Department, Lucknow University, Lucknow.
- 29-2-32 Deb, Suresh Chandra, D.Sc., Research Physicist, Bose Institute, Calcutta.
- 17-4-31 * Deodhar, D. B., Ph.D., Reader, Physics Department, Lucknow University, Lucknow.
- 31-10-35 Desai, M. S., M.Sc., Professor of Physics, M.T.B. College, Surat.
- 17-4-31 * Dey, P. K., M.Sc., I.A.S., Principal, Government Agricultural College, United Provinces, Cawnpore.
- 1-1-30 † * Dhar, N. R., D.Sc., Docteur ès Sciences, F.I.C., I.E.S., Deputy Director of Public Instruction, U. P., Allahabad
- 31-10-35 Dube, Ganesh Prasad, M.Sc., Lecturer in Physics, Balwant Rajput College, Agra.
- 23-4-37 Dubey, V. S., M.Sc., Ph.D., D.I.C., Professor of Economic Geology, Hindu University, Benares.
- 28-10-32 Dutt, A. K., D.Sc., Research Physicist, Bose Research Institute, Calcutta.
- 17-4-31 † * Dutt, S. B., D.Sc., Reader, Chemistry Department, Allahabad University, Allahabad.
- 19-3-31 * Dutt, S. K., M.Sc., D.Sc. (Alld.), Zoology Department, Allahabad University, Allahabad.
- 1-2-37 Gandhi, Darabshaw J., Esq., Agricultural Engineering Deptt., U. P., Cawnpore.
- 20-4-36 Ganguly, P. B., D.Sc., Professor of Chemistry, Science College, Bankipore P.O., Patna.
- 22-2-23 Ghatak, Narendranath, M.Sc., D.Sc., Chemical Assistant, Indian Stores Department, Government Test House, Alipore, Calcutta.
- 20-4-36 † * Ghosh, J., M.A., Ph.D., Professor of Mathematics, Presidency College, Calcutta.
- 8-11-30 † * Ghosh, J. C., D.Sc., Director, Indian Institute of Science, Bangalore.
- 19-3-31 † * Ghosh, R. N., D.Sc., Physics Department, Allahabad University, Allahabad.
- 19-3-31 * Ghosh, Satyeshwar, D.Sc., Chemistry Department, Allahabad University, Allahabad.
- 20-4-36 † * Ghose, S. L., Ph.D., Professor of Botany, Government College Lahore.
- 17-4-31 * Gupta, B.M., Ph.D., Deputy Public Analyst to Government, United Provinces, Lucknow.

Date of
Election

Alphabetical List of Members

10-5-37		Gupta, K. M., M.Sc., D.Sc., Professor of Biology, M.T.B. College, Surat.
17-4-31		Higginbottom, Sam, D.Phil., Principal, Allahabad Agricultural Institute, Naini, E. I. R., Allahabad.
10-5-37	† *	Husain, M. Afzal, Khan Bahadur, M.A. (Cantab.), M.Sc., I.A.S., Vice-Chancellor, Punjab University, Lahore.
21-12-36		Husain, Zahur, B.A. (Hons.), c/o K. B. Nur Husain Shah, D. S. Police, Amritsar (Punjab).
10-5-37		Ishaq, Mohammad, Ph.D., Physics Deptt., Muslim University, Aligarh, U. P.
20-4-36	*	John, C. C., Director of Fisheries, Travancore, S. I.
4-9-39	† *	Joshi, A. C., D.Sc., Asstt. Professor of Botany, Benares Hindu University, Benares.
3-4-34		Joshi, A. D., P.E.S., Lecturer, Training College, Lucknow.
10-5-37		Kalapesi, A. S., B.A., B.Sc., D.I.C., Ph.D., F.R.G.S., Professor, St. Xavier's College, Cruickshank Road, Fort, Bombay.
10-5-37		Khan, A. S., M.Sc., D.D.P.L., Bihar, 7 Strand Road, Patna.
15-9-31	† *	Kichlu, P. K., D.Sc., Department of Physics, Government College, Lahore.
21-4-33		Kishen, Jai, M.Sc., Professor of Physics, S.D. College, Lahore.
9-2-34	† *	Kothari, D. S., M.Sc., Ph.D., Professor of Physics, Delhi University, Delhi.
3-4-34	† *	Krishna, Shri, Ph.D., D.Sc., F.I.C., Forest Biochemist, Imperial Forest Research Institute, Dehra Dun.
5-10-33	*	Kureishy, A. M., M.A., Reader in Mathematics, Muslim University, Aligarh.
31-10-35		Lal, Rajendra Bihari, M.Sc., Assistant Traffic Superintendent, E. I. R., Chief Commercial Manager's Office, Calcutta.
1-1-30	† *	MacMahon, P. S., B.Sc. (Hons.), M.Sc., Professor of Chemistry, Lucknow University, Lucknow.
10-5-37		Mahabale, T. S., B.A., M.Sc., Deptt. of Biology, Gujarat College, Ahmedabad.
31-10-35	† *	Maheshwari, Panchanan, D.Sc., Head of the Botany Department, The University, Dacca.
31-10-35		Majumdar, R. C., M.Sc., Ph.D., Bose Research Institute, 93 Upper Circular Road, Calcutta.
25-3-39		Malik, I., Director of Veterinary Services (Behar), Wheeler Road, Patna.

Date of Election		Alphabetical List of Members
10-5-37		Mathur, A. P., M.Sc., D.I.C., D.Sc., Principal, Darbar Intermediate College, Rewa, C.I.
31-10-35	*	Mathur, K. N., D.Sc., Lecturer in Physics, Lucknow University, Lucknow.
31-10-35		Mathur, Lakshmi Sahay, M.Sc., Upper Air Observatory, Agra
8-11-33	*	Mathur, Ram Behari, M.Sc., Professor of Mathematics, St. Stephen's College, Delhi
17-12-35	† *	Matthai, George, M.A., Sc.D., F.R.S.E., I.E.S., Professor of Zoology, Punjab University, Lahore.
19-3-31	*	Mazumdar, Kanakendu, D.Sc., Physics Department, Allahabad University, Allahabad.
1-1-30	† *	Mehta, K. C., Ph.D., M.Sc., Agra College, Agra
19-3-31	† *	Mehra, H. R., Ph.D., Reader, Zoology Department, Allahabad University, Allahabad.
23-4-37	*	Misra, Avadh Bihari, D.Sc., D.Phil., Deptt. of Zoology, Benares Hindu University, Benares.
31-10-35		Mohan, Ananda, B.Sc., Assistant Traffic Superintendent, E.I.R., Chief Commercial Manager's Office, 105 Clive Street, Calcutta.
20-4-35	† *	Mowdawalla, F. N., M.A., M.I.E.E., Mem. A.I.E.E., M.I.E., 301, Frere Road, Fort, Bombay.
1-1-30	*	Narayan, Luxmi, D.Sc., Reader, Mathematics Department, Lucknow University, Lucknow.
22-2-33	† *	Narliker, V. V., M.A., Professor of Mathematics, Benares Hindu University, Benares.
23-4-37	*	Nath, Raj, D.I.C., Ph.D., Deptt. of Geology, Benares Hindu University, Benares.
20-4-35	† *	Normand, C.W.B., M.A., D.Sc., Director General of Observatories, Poona.
31-10-35		Oak, V. G., M.Sc., I.C.S., Additional District Judge, Jhansi.
16-8-35		Pande, Kedar Dat, M.Sc., Lecturer, Training College, Agra.
17-4-31	*	Pandya, K. C., Ph.D., St. John's College, Agra.
3-4-33	† *	Parija, P. K., M.A., I.E.S., Ravenshaw College, Cuttack.
10-5-35	† *	Pinfold, Ernest Sheppard, M.A., F.G.S., Geologist, Attock Oil Co., Ltd., Rawalpindi.
18-9-35	*	Pramanik, S. K., M.Sc., Ph.D., D.I.C., Meteorologist, The Observatory, Alipur, Calcutta.
3-4-33	† *	Prasad, Badri Nath, Ph.D., Docteur es Sciences, Mathematics Department, Allahabad University, Allahabad.

Date of
Election

Alphabetical List of Members

5-10-33	* Prasad, Gorakh, D.Sc., Reader in Mathematics, Allahabad University, Allahabad.
21-4-33	* Prasad, Kamta, M.A., M.Sc., Professor of Physics, Science College, P. O. Bankipore (Patna).
15-9-31	† * Prasad, Mata, D.Sc., Royal Institute of Science, Bombay.
10-5-37	Prasad, Shiva Parbati, M.A. (Cantab.), Professor of Physics, Science College, Patna.
10-5-37	Rahimullah, M., M.Sc., Lecturer in Zoology, Osmania University, Hyderabad.
10-5-37	Rahman, Wahidur, B.Sc. (Cal.), Professor of Physics, Osmania University, Hyderabad, Deccan.
20-12-34	Rai, Ram Niwas, M.Sc., Physics Department, Allahabad University, Allahabad.
15-9-37	Raina, Shyam Lal, M.Sc., Professor of Biology, S. P. College, Srinagar, Kashmir.
3-4-33	* Ram, Raja, M.A., B.E., Professor of Civil Engineering, Thompson College, Roorkee.
10-5-37	Ramiah, K., Geneticist and Botanist, Institute of Plant Industry, Indore.
23-4-37	Randhawa, M. S., I.C.S., Additional Collector, 2A, Park Road, Allahabad.
10-5-35	† * Rangaswami, Ayyangar, G. N., Rao Bahadur, B.A., I.A.S., Millets Specialist to the Government of Madras, Agricultural Research Institute, P.O. Lawley Road, Coimbatore.
19-3-31	* Ranjan, Shri, M.Sc. (Cantab.), Docteur ès Sciences, Reader, Botany Department, Allahabad University, Allahabad.
15-9-31	* Rao, A. Subba, D.Sc., Department of Zoology, Central College, Bangalore.
22-2-33	Rao, G. Gopala, B.A., M.Sc., D.Sc., Chemistry Department, Andhra University, Waltair.
20-4-35	* Rao, I. Rama Krishna, M.A., Ph.D., D.Sc., Department of Physics, Andhra University, Waltair.
14-3-34	† * Rao, K. Rangadharma, D.Sc., Physics Department, Andhra University, Waltair.
22-2-33	† * Ray, Bidhubhusan, D.Sc., 92, Upper Circular Road, Calcutta.
1-2-36	* Ray, J. P., M.Sc., Professor, D.A.V. College, Dehra Dun.
10-5-37	Ray, Ramesh Chandra, D.Sc., F.I.C., Professor of Chemistry, Science College, Patna.

Date of
Election

Alphabetical List of Members

21-12-31		Ray, Satyendra Nath, M.Sc., Physics Department, Lucknow University, Lucknow.
23-4-37		Rode, K.P., M.Sc., Asst. Professor of Geology, Benares Hindu University, Benares.
29-2-32		Saha, Jogendra Mohan, M.Sc., Manager, Sitalpur Sugar Works, P.O. Digwara, Dist. Saran.
1-1-30	† *	Saha, M.N, D.Sc., F.R.S., F.A.S.B., F. Inst P., P.R.S., Palit Professor of Physics, University College of Science, 92, Upper Circular Road, Calcutta.
1-1-30	† *	Sahni, B., D.Sc., Sc.D., F.R.S., Professor of Botany, Lucknow University, Lucknow.
17-4-31	*	Sane, S. M., B.Sc., Ph.D., Reader, Chemistry Department, Lucknow University, Badshah Bagh, Lucknow.
1-2-36	*	Saxena, Ram Kumar, D.Sc., Lecturer in Botany, Allahabad University, Allahabad.
10-5-37	*	Sayeeduddin, M., M.A., B.Sc., Professor of Botany, Osmania University, Hyderabad, Deccan.
31-10-35	† *	Sen, Jitendra Mohan, M. Ed., B.Sc., Teacher's Dip., F.R.G.S., D.Ed., Principal, Krishnagar College, Krishnagar.
3-4-33	*	Sen, K. C., D.Sc., Officer-in-charge, Animal Nutrition Section, Imperial Veterinary Research Institute, Izatnagar, U. P.
20-4-35	† *	Sen, Nikhil Ranjan, D.Sc., Professor of Mathematics, 92, Upper Circular Road, Calcutta.
17-12-35	† *	Sen Gupta, N. N., Ph.D., Professor of Psychology, Lucknow University, Lucknow.
20-12-34	*	Sen Gupta, P.K., D.Sc., Asstt. Meteorologist, Indian Meteorological Office, Alipur, Calcutta.
19-3-31	*	Sethi, Nihal Karan, D.Sc., Agra College, Agra.
31-10-35	*	Shabde, N. G., D.Sc., Professor of Mathematics, College of Science, Nagpur.
10-5-37		Sharma, Dhyan Swarup, B.Sc., 40, Kaiserbagh, Lucknow.
31-10-35		Sharma, P. N., M.Sc., Physics Department, Lucknow University, Lucknow.
15-9-31		Sharma, Ram Kishore, M.Sc., Physics Department, Ewing Christian College, Allahabad.
18-9-33		Shukla, Janardan Prasad, M.Sc., Indian Institute of Sugar Technology, Cawnpore.

Date of
Election

Alphabetical List of Members

- 3-4-33 † * Siddiqi, M.R., Ph.D., Professor of Mathematics, Osmania University, Hyderabad, Deccan.
- 3-4-33 * Siddiqui, Mohammad Abdul Hamid, M.A., M.S., F.R.C.S., D.L.O., Professor of Anatomy, King George's Medical College, Lucknow.
- 10-5-37 † * Singh, Bawa Kartar, M. A. (Cantab), Sc.D., F.I.C., I.E.S., Professor of Chemistry, Science College, and Chemical Adviser to the Department of Industries, Bihar, Patna.
- 17-12-35 * Singh, Bhola Nath, D.Sc., Kapurthala Professor of Agricultural Botany and Plant Physiology, Head of the Institute of Agricultural Research, Hindu University, Benares.
- 10-5-37 Singh, T. C. N., D.Sc., Asst. Economic Botanist, In-charge, Botanical Section, Sabour (Bihar).
- 18-9-35 Srivastava, Bishwambhar Nath, M.Sc., D.Sc. (Alld.), Lecturer, Physics Department, Allahabad University, Allahabad.
- 4-9-39 Srivastava, Girja Dayal, M.Sc., Lecturer in Botany, Allahabad University, Allahabad.
- 19-3-31 † * Srivastava, P. L., Rai Sahib, M.A., D.Phil., Reader, Mathematics Department, Allahabad University, Allahabad.
- 10-8-33 * Srivastava, R. C., B.Sc. (Tech.), Sugar Technologist, Imperial Council of Agricultural Research, India, Cawnpore.
- 15-9-31 * Srikantia, C., B.A., D.S., Medical College, Mysore.
- 19-12-32 * Strang, J. A., M.A., B.Sc., Professor of Mathematics, Lucknow University, Lucknow.
- 17-4-31 † * Sulaiman, Hon'ble Sir, S. M., Kt, M.A., LL.D., D.Sc., Judge, Federal Court of India, Delhi.
- 20-4-36 † * Sur, N. K., D.Sc., Meteorologist, Meteorological Department, Poona.
- 17-12-35 Tandon, Amar Nath, M.Sc., D.Phil., Physics Department, Allahabad University, Allahabad.
- 9-11-35 Tandon, Prem Narain, M.Sc., I.C.S., Under-Secretary to Govt., Political and Apptt. Deptt., Patna.
- 4-9-39 Tewari, Sri Govind, M.A., Mathematics Department, Allahabad University, Allahabad.
- 19-3-31 * Toshniwal, G. R., M.Sc. (Alld.), D.Sc. (Alld.), Physics Department, Allahabad University, Allahabad.
- 15-9-36 Trivedi, Hrishikesh, M.Sc., D.Sc., Physical Assistant, Government Test House, Judge's Court Road, Alipur (Calcutta).

Date of
Election

Alphabetical List of Members

3-4-34		Varma, Rama Shanker, M.Sc., Christ Church College, Cawnpore.
9-2-34		Vaugh, Mason, B.Sc. (Ing.), Agricultural Engineer, Allahabad Agricultural Institute, Naini, (Allahabad).
19-3-31	† *	Vijayaraghavan, T., D.Phil., Reader, Mathematics Department, Dacca University, Ramna, Dacca.
20-4-35	† *	Vishwanath, B., Rao Bahadur, F.I.C., Director, Imperial Agricultural Research Institute, New Delhi.
20-4-35	† *	Wadia, D. N., M.A., B.Sc., F.G.S., F.R.G.S., Deptt. of Mineralogy, Columbo, Ceylon.
1-1-30	*	Wali, Mohammad, Ch., M.A., Ph.D., I.E.S., Professor of Physics, Lucknow University, Lucknow.

N.B.—The Secretaries will be highly obliged if the members will kindly bring to their notice errors, if there be any, in their titles, degrees, and addresses.

APPENDIX 8

LIST OF EXCHANGE JOURNALS

INDIAN

Publishers	Journals
BANGALORE	
The Indian Academy of Sciences	Proceedings of the Indian Academy of Sciences, Section A
"	" Section B
The Indian Institute of Science	Journal of the Indian Institute of Science, Section A
"	" Section B
"	Quarterly Journal of the Indian Institute of Science
"	Current Science
Department of Electrical Technology, Indian Institute of Science	Electrotechnics
Society of Biological Chemists, India	Proceedings of the Society of Biological Chemists, India
BOMBAY	
Haffkine Institute	Report of the Haffkine Institute
CALCUTTA	
Asiatic Society of Bengal	Journal of the Asiatic Society of Bengal (Letters)
"	Journal of the Asiatic Society of Bengal (Science)
"	Year Book
"	Journal and Proceedings of the Asiatic Society of Bengal
"	Proceedings of the Indian Science Congress
National Institute of Sciences of India	Transactions of the National Institute of Sciences of India
"	Indian Science Abstracts
"	Proceedings of the National Institute of Sciences of India

Publishers

Journals

CALCUTTA

National Institute of Sciences of
India.

Indian Association for Cultivation of
Science

Bose Research Institute

Indian Science News Association

Indian Chemical Society

Oxford University Press

Calcutta University

Report of the Council of the National
Institute of Sciences of India

Indian Journal of Physics and Proceed-
ings of the Indian Association for
the Cultivation of Science

Transactions of the Bose Research
Institute

Science and Culture

The Journal of the Indian Chemical
Society

Indian Physico-Mathematical Journal
Journal of the Department of Science

COONOR

Nutrition Research Laboratories

Publications of the Laboratories
(Publication discontinued from 1938)

MADRAS

Department of Fisheries

Madras Government Museum

Journals, Administration Report

Bulletin of the Madras Government
Museum, Natural History Section

NEW DELHI

Industrial Research Bureau

Imperial Council of Agricultural
Research

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Bulletin of the Indian Industrial
Research

Indian Journal of Agricultural Science

Indian Journal of Veterinary Science
and Animal Husbandry

Scientific Monographs of the Imperial
Council of Agricultural Research

Agriculture and Livestock in India

Annual Report

Indian Farming

NAGPUR

Nagpur University

Nagpur University Journal

Publishers**Journals****HYDERABAD (DECCAN)**

Osmania University

Journal of the Osmania University

PATNAPhilosophical Society, Science College,
Patna.Bulletin of the Patna Science College
Philosophical Society**POONA**

Indian Meteorological Department

Scientific Notes

"

Memoirs of the Indian Meteorological
Department

"

Seismological Bulletin

FOREIGN**AUSTRALIA****ADELAIDE**

The Royal Society of South Australia

Transactions of the Royal Society of
South Australia**EAST MELBOURNE**Council for Scientific and Industrial
ResearchJournal of the Council for Scientific and
Industrial Research

"

Pamphlet of the Council for Scientific
and Industrial Research

"

Annual Report

Radio, Research Board Council for Sci-
entific and Industrial Research

Bulletin of the Radio Research Board

MELBOURNE

Royal Society of Victoria

Proceedings of the Royal Society of
Victoria

"

Annual Report

SYDNEY

Royal Society of New South Wales

Journal and Proceedings of the Royal
Society of New South Wales

Publishers

Journals

AUSTRIA

VIENNA

Akademie der Wissenschaften

Anzeiger (Mathematisch-naturwissen-
schaftliche Klasse)

„

Anzeiger (Philosophisch-historische
Klasse)

„

Almanach

BELGIUM

BRUSSELS

L'Academie Royale de Belgique

Bulletin de la Classe des Sciences

„

Annuaire de l'Academie Royale de
BelgiqueCANADA

OTTAWA

The Royal Society of Canada

Transactions of the Royal Society of
Canada

„

Biological Sciences

The National Research Council

Annual Report

TORONTO

The Royal Astronomical Society of
CanadaJournal of the Royal Astronomical
Society of Canada

VICTORIA

The Dominion Astrophysical Obser-
vatoryPublications of Dominion Astrophysical
ObservatoryCHINA

NANKING

National Research Institute of Bio-
logy, Academia Sinica

Sinensia

Zoological Society of China, Acade-
mia Sinica

Chinese Journal of Zoology

National Research Institute of Che-
mistry, Academia SinicaMemoir of the National Research
Institute of Chemistry

SHANGHAI

National Research Institute of Phy-
sics, Academia SinicaScientific Papers of the National Re-
search Institute of Physics

Publishers**Journals****DENMARK****COPENHAGEN**

Det Kgl. Danske Videnskabernes
Selskab.

Mathematisk-fysiske Meddelelser

"

Biologiske Meddelelser

L'Academie Royale des Sciences et
des Letters de Denmark

Mémoires de l'académie Royale des
Sciences et des Letters de Denmark

Laboratoire Carlsberg

Comptes-Rendus des Travaux du
Laboratoire Carlsberg

EGYPT**CAIRO**

The Egyptian Medical Association

Journal of the Egyptian Medical Asso-
ciation

Head of the Faculty of Medicine

Tremetodes of Fishes from Red Sea

ENGLAND**ABERDEEN**

Imperial Bureau of Animal Nutrition

Technical Communications

ABERYSTWYTH

Imperial Bureau of Plant Genetics;
Herbage Plants.

Bulletins

ST. ALBANS, HERTS

Imperial Bureau of Agricultural
Parasitology

Helminthological Abstracts

"

Bibliography of Helminthology

CAMBRIDGE

Imperial Bureau of Plant Genetics,
School of Agriculture

Plant Breeding Abstracts

The Philosophical Society

Proceedings of the Cambridge Phi-
losophical Society

EDINBURGH

The Royal Society of Edinburgh

Proceedings of the Royal Society of
Edinburgh

Publishers

Journals

HARPENDEN

Imperial Bureau of Soil Science,
Rothamsted Experimental Station

Technical Communications

"

Soils and Fertilizers

"

Reprints

"

Reports

"

Pamphlets

EAST MALLING, KENT

Imperial Bureau of Fruit Production

Horticultural Abstracts

LONDON

The Electrician, Bouverie House

Electrician

TEDDINGTON, MIDDLESEX

The National Physical Laboratory

Reports of the National Physical
Laboratory

"

Collected Researches of the National
Physical Laboratory

FRANCE

PARIS

L'Institute Henri Poincaré
De La Station Biologique de Roscoff

Annales de l'Institute Henri Poincaré
Travaux de la Station Biologique de
Roscoff

RENNES

De La Société Scientifique de
Bretagne

Bulletin de la Société Scientifique de
Bretagne

GERMANY

BERLIN

Preussischen Akademie der Wissens-
chaften
Deutschen Chemischen Gesellschaft

Sitzungsberichte Der Preussischen
Akademie
Berichte Der Deutschen Chemischen
Gesellschaft

Publishers	Journals
GOTTINGEN	
Gesellschaften Wissenschaften zu Gottingen	Nachrichten von der Gesellschaft der Wissenschaften zu Gottingen Mathematisch-Physikalische Klasse Fachgruppe I. Mathematik
"	" II. Physik, Astronomie, Geophysik Technik
"	" III. Chemie, einschl. Physikalische Chemie.
"	" IV. Geologie und Mineralo- gie
"	" V. Geographie
"	" VI. Biologie
"	Geschäftliche Mitteilungen
HEIDELBERG	
Heidelberger Akademie der Wissens- chaften	Sitzungsberichte der Heidelberger Akademie der Wissenschaften, Mathematisch-naturwissenschaft- liche Klasse
LEIPZIG	
Sachsische Akademie der Wissens- chaften	Berichte der Mathematisch Physis- chen Klasse
"	Abhandlungen der Mathematisch- Physischen Klasse
MUNCHEN	
Bayerischen Akademie der Wissens- chaften zu München	Sitzungsberichte der Mathematisch- naturwissenschaftlichen Abteilung
<u>HOLLAND</u>	
GRONINGEN	
Kapteyn Astronomical Laboratory	Publications of the Kapteyn Astrono- mical Laboratory
LEIDEN	
Kamerlingh Onnes Laboratory of the University of Leiden	Communications from the Physical Laboratory of the University of Leiden
	Communications from Kamerlingh Onnes Laboratory

Publishers

Journals

HUNGARY

BUDAPEST

Der Ungarischen Akademie der Wissenschaften	der Mathematischer und schaftlicher Anzeiger	Naturwissen
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ITALY

PALERMO

Circolo Mathematico di Palermo

Rendiconti del Circolo Mathematico di Palermo

ROME

International Institute of Agriculture

Monthly Bulletin of Agricultural Science and Practice

VENICE

Centro Volpi Di Elettrologia

Bulletin of the Centro Volpi Di Elettrologia

JAPAN

HIROSHIMA

Hiroshima University

Journal of Science of the Hiroshima University, Series A

KEIJO

Medical Faculty, Keijo Imperial University

The Keijo Journal of Medicine

KYOTO

Physico-chemical Society of Japan, Kyoto Imperial University

Review of Physical Chemistry of Japan

OSAKA

The Faculty of Science, Osaka Imperial University

Collected Papers from the Faculty of Science

Collected Papers from the Faculty of Medicine

SAPPORO

The Faculty of Science, Hokkaido Imperial University

Journal of the Faculty of Science, Series I, Mathematics

SENDAI

Imperial University of Tohoku

Science Reports of the Tohoku Imperial University

Publishers

Journals

TOKYO

The Imperial Academy	Proceedings of the Imperial Academy
The Institute of Physical and Chemical Research	Scientific Papers
The National Research Council of Japan	Japanese Journal of Mathematics
"	Japanese Journal of Botany
"	Japanese Journal of Physics
"	Japanese Journal of Astronomy and Geophysics
"	Report
"	Report of Radio Research
The Physico-Mathematical Society of Japan	Proceedings of the Physico-Mathematical Society of Japan

MANCHOUKUO

HSINCHING

The Institute of Scientific Research	Report of the Institute of Scientific Research
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NEW ZEALAND

WELLINGTON

Royal Society of New Zealand	Transactions and Proceedings of the Royal Society of New Zealand
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PHILIPPINE ISLANDS

MANILA

Bureau of Sciences, Department of Agriculture and Commerce	Philippine Journal of Science
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POLAND

CRACOVIE

Académie Polonoise des Sciences et des Lettres	Comptes Rendus Mensuels des Séances de la classe des Sciences Mathématiques et Naturelles
"	Comptes Rendus Mensuels des Séances de la classe de Médecine

Publishers

Journals

CRACOVIE

Académie Polonoise des Sciences et
des Lettres

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Polska Akademia Umiejetności

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Bulletin International, classe des Scien-
ces Mathématiques et Naturelles,
Série A: Sciences MathématiquesBulletin International, classe des Scien-
ces Mathématiques et Naturelles, Série
B: Sciences Naturelles (I)Bulletin International, classe des Scien-
ces Mathématiques et Naturelles,
Série B: Sciences Naturelles (II)Memoires, classe des Sciences Mathé-
matiques et Naturelles, Série A:
Sciences MathématiquesMemoires, classe des Sciences Mathé-
matiques et Naturelles, Série B: Scien-
ces NaturellesBulletin International, classe de Mé-
decineMemoires classe de Médecine
Starunia

Travanz Geologiques

WARSAW

Société des Sciences et des Lettres de
Varsovie

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Polish Physical Society

Comptes Rendus des Séances, class I
(jezykoznawstwa i historii literatury)Comptes Rendus des Séances, class II
(historycznych, społecznych i filozo-
ficznych)Comptes Rendus des Séances, class III
(matematyczno-fizycznych)Comptes Rendus des Séances, class IV
(bilogicznych)

Acta Physica Polonica

ROMANIA

JASSY

Universitatia Din Jasi, Seminarul
Matmatic

Annals Scientifique.

Publishers

Journals

SOUTH AFRICA

CAPE TOWN

Royal Society of South Africa

Transactions of the Royal Society of
South AfricaSWEDEN

LUND

Kungl. Fysiografiska Sällskapet

Kungl. Fysiografiska Sällskapets For-
handlingar

STOCKHOLM

Kungl. Svenska Vetenskapsakademie

Kungl. Svenska Vetenskapsakademiens
Handlingar

UPPSALA

Uppsala Universitet

Uppsala Universitets Årsskrift

SWITZERLAND

GENEVA

Société de Physique et d' Histoire
Naturelle de GenèveCompte Rendu des Séances de La
Société de Physique et d' Histoire
Naturelle de GenèveUNION OF SOVIET SOCIALIST REPUBLICS

KHARKOV

Chaikovsakaya 16

Physikalische Zeitschrift der Sowjet-
Union (*stopped after March, 1938*)

LENINGRAD

The Akademie der Wissenschaften

Bulletin de l'Academie des Sciences
Mathématiques et Naturelles

MOSCOW

De l'Académie des Sciences de
l'URSS

Comptes Rendus (Doklady)

De l'Académie des Sciences de
l'URSSBulletin de l'Académie des Sciences
de l'URSS classe des Sciences Mathé-
matiques et Naturelles

Publishers**Journals****UKRAINE**

Academie des Sciences d'Ukraine,
Kyive

Journal du Cycle Physique et de Chemie

"

Journal du Cycle Mathématique

"

Bulletin de la classe des Sciences Physique et Mathématiques

UNITED STATES OF AMERICA**ALLEGHENY CITY**

Allegheny Observatory of the University of Pittsburgh

Publications of the Allegheny Observatory

BOSTON

American Academy of Arts and Sciences

Proceedings of the American Academy of Arts and Sciences

"

Memoirs of the American Academy of Arts and Sciences

RIO DE JANEIRO

Instituto Oswaldo Cruz

Memorias do Instituto Oswaldo Cruz

CALIFORNIA

The Mount Wilson Observatory

Contributions from the Mount Wilson Observatory

"

Communications from the Mount Wilson Observatory

"

Annual Report of the Director of the Mount Wilson Observatory

University Library

Publications in Zoology, University of California

Lick Observatory, University of California

Lick Observatory Bulletin

CAMBRIDGE MASS.

Massachusetts Institute of Technology

Journal of Physics and Mathematics

Publishers

Journals

CHICAGO

The University of Chicago

Astrophysical Journal

LAWRENCE, KANSAS

The University of Kansas

Science Bulletin

MICHIGAN

Observatory Library, University of
MichiganPublications of the Observatory of the
University of Michigan

NEW YORK

Bell Telephone Laboratories

Bell Telephone System Technical Pub-
licationsAmerican Telephone and Telegraph
Company

Bell System Technical Journal

Roosevelt Wild Life Forest Experi-
ment Station

Roosevelt Wild Life Annals

The American Museum of Natural
History

American Museum Novelties

New York Academy of Sciences

Annals of the New York Academy of
Sciences

American Institute of Physics

Review of Scientific Instruments

"

Journal of Chemical Physics

NEW HAVEN, YALE

Astronomical Observatory of Yale
UniversityTransactions of the Astronomical Ob-
servatory, Yale University

American Journal of Science

American Journal of Science

PHILADELPHIA

The Franklin Institute of the State of
Pennsylvania

Journal of the Franklin Institute

American Philosophical Society

Proceedings of the American Philoso-
phical Society

Academy of Natural Sciences

Proceedings of the Academy of Natural
Sciences of Philadelphia

"

Miscellanea

"

Library Annual Report

Publishers

Journals

WOODS HALE MASS.

Marine Biological Laboratory Library

The Biological Bulletin

WASHINGTON

The National Academy of Sciences

Proceedings of the National Academy
of Sciences"
Smithsonian InstituteBiographical Memoirs
PublicationsDepartment of Commerce, National
Bureau of Standard Library

Publications of the Bureau of Standards

The Commissioner of Fisheries

Publications

Carnegie Institute of Washington

Magnetic Observations of Sun spots

SOUTH AMERICA

MONTEVIDEO—Uruguay

Archivos De La Sociedad Biologia De

Sociedad de Biologia de Montevideo

Montevideo

APPENDIX 9

LIST OF PAPERS COMMUNICATED TO THE ACADEMY DURING

JANUARY, 1939—DECEMBER, 1939

(Arranged Alphabetically)

1. Annotated List of the Helminths Recorded from Domesticated Animals of Burma Part II—Cestoda, by R. C. Chatterji, Helminthological Institute, University of Rangoon. (Communicated by Dr. H. R. Mehra.)
2. Carnot's Cycle and the Six Thermodynamic Relations, by S. B. L. Mathur, The University, Delhi. (Communicated by Dr. D. S. Kothari.)
3. Certain Inconsistencies in the Mathematical Theory of A New Relativity of Dr. Sir Shah Sulaiman, by S. K. Roy, Allahabad University. (Communicated by Rai Sahib Dr. P. L. Srivastava.)
4. Chemical Examination of Essential Oil *Curcuma caesia*, by B. K. Malaviya and Sikhibhushan Dutt, Chemistry Department, Allahabad University.
5. Chemical Examination of the Essential Oil of *Hedychium spicatum* Ham, by Jagat Narain Tayal and Sikhibhushan Dutt, Chemistry Department, Allahabad University.
6. Chemical Examination of the Essential Oil from the Peels of Nagpur Oranges, by B. K. Malaviya and S. Dutt, Chemistry Department, Allahabad University.
7. Chemical Examination of the Fixed Oil from the Seeds of *Euphorbia dracunculoides* Lam, by Jagat Narain Tayal and S. Dutt, Chemistry Department, Allahabad University.
8. Chemical Examination of the Leaves of *Nepeta ruderalis* Hamilt. Composition of the Essential Oil, by Jagat Narain Tayal and Sikhibhushan Dutt, Chemistry Department, Allahabad University.
9. Chemical Examination of the Seeds of *Martynia diandra*. Composition of the Fixed Oil, by Jagat Narain Tayal and Sikhibhushan Dutt, Chemistry Department, Allahabad University, Allahabad.
10. Colour in Relation to Chemical Constitution of the Organic and Inorganic Salts of Isonitroso-Malonyl-Guanidine, by Ione Nitravati Dharam Dass and Sikhibhushan Dutt, Chemistry Department, Allahabad University.
11. Composition of Patent Still Molasses Fusel Oil of Indian Origin, Part II, by Shikhibhushan Dutt, Chemistry Department, Allahabad University, Allahabad.

12. Constitution of Cuscutalin, by Mahadeo Prasad Gupta, Jagraj Behari Lal and Sikhibhushan Dutt, Chemistry Department, Allahabad University, Allahabad.
13. Constituents of *Pterocarpus dalbergioides*, Roxb., by Jagraj Behari Lal and S. B. Dutt, Chemistry Department, Allahabad University.
14. Contribution to the Morphology of *Orobanchae aegyptiaca* Pers., by Girja Dayal Srivastava, Botany Department, Allahabad University, Allahabad.
15. Essential Oil from the Seeds of *Zanthoxylum alatum* Roxb., by Jagat Narain Tayal, J. B. Lal and S. Dutt, Chemistry Department, Allahabad University.
16. Formation of periodic precipitate in the absence of a foreign gel, Part III, Ferric phosphate and ferric arsenate sols., by R. N. Mitra, Chemistry Department, Allahabad University, Allahabad. (Communicated by Prof. K. P. Chatterji.)
17. Formation of periodic precipitate in the absence of a foreign gel, part IV, Ferric Borate sol., by R. N. Mitra, Chemistry Department, Allahabad University, Allahabad. (Communicated by Prof. K. P. Chatterji.)
18. Infinitesimal Transformations admitted by the action form and the Hamiltonian, I, by K. Nagabhushan, Mathematics Department, Andhra University, Waltair. (Communicated by Dr. G. Gopala Rao.)
19. Infinitesimal Transformations admitted by the action form and the Hamiltonian, II., by K. Nagabhushan, Mathematics Department, Andhra University, Waltair. (Communicated by Dr. G. Gopala Rao.)
20. Influence of Concentration on Chemical Reactivity and Light Absorption, by A. K. Bhattacharya, and S. P. Agarwal, Chemistry Department, Allahabad University.
21. Intermittent Discharge in Mercury Vapours, by Mohd. Aslam, Abdul Waheed Khan and R. M. Chaudhri, Physics Department, Muslim University, Aligarh.
22. Kinetics of Slow Coagulation of Sols by Electrolytes, by B. Chakravarti and S. Ghosh, Chemistry Department, Allahabad University.
23. New Blood Flukes of the Family Spirorchidae Stunkard (Trematoda) from the Marine Turtle *Chelone mydas* of the Arabian Sea with observations on the Synonymity of Certain Genera and Classification of the Family. by H. R. Mehra, Zoology Department, Allahabad University.
24. New Monostomes of the Family Pronocephalidae Looss, 1901, by Ram Krishna Mehra, Zoology Department, Allahabad University, Allahabad. (Communicated by Dr. H. R. Mehra)

25. New Series of Extremely Sensitive and Estimation of Ferrous Iron in Traces, by Dr. Sikhibhushan Dutt, Chemistry Department, Allahabad University.
26. Note on Sir Shah Sulaiman's Mathematical Theory of A New Relativity, by Sunil Kumar Roy, Govt. Intermediate College, Allahabad. (Communicated by Rai Sahib Dr. P. L. Srivastava.)
27. Nutrition of some species of the genus *Pythium* in Synthetic Liquid media, by Dr. Ram Kumar Saksena, Botany Department, Allahabad University.
28. Observations on the Development of Zoosporangium and Liberation of Zoospores in *Achlya dubia* Coker, by M. S. Murdia, Botany Department, Allahabad University. (Communicated by Dr. Ram Kumar Saksena.)
29. Polotropic gas models with variable angular velocity, by P. L. Bhatnagar, Mathematics Department, Allahabad University, Allahabad. (Communicated by Prof. A. C. Banerji)
30. Radion and the Electro-Magnetic Whirl, by Dr. N. S. Japolsky, Royal Institution, 21, Albemarle Street, London. (Communicated by Sir Shah Muhammad Sulaiman.)
31. Studies on the effect of ethylene on the ripening process of Guava (*Psidium guava*), by S. Ranjan and G. N. Sapru, Botany Department, Allahabad University.
32. Studies on the effect of ethylene and sulphur dioxide on the fruits of *Mangifera indica*, by S. Ranjan and V. R. Jha, Botany Department, Allahabad University.
33. Tables of Symmetric Functions for Statistical Purposes, by Dr. M. Ziauddin, Mathematics Department, Muslim University, Aligarh. (Communicated by Dr. Ram Behari).
34. The Action form and Jacobi's last Multiplier, by K. Nagabhushan, Mathematics Department, Andhra University, Waltair. (Communicated by Dr. G. Gopala Rao.)
35. The Importance of the Primary Absorption Process in Photo-Chemical Reactions, by A. K. Bhattacharya, Chemistry Department, Allahabad University.
36. Theory of Zinck's Reaction, by Jagraj Behari Lal, Chemistry Department, Allahabad University. (Communicated by Dr. S. B. Dutt.)

APPENDIX 10

FINANCIAL STATEMENT OF RECEIPTS AND EXPENDITURE FROM 1ST APRIL, 1939, TO 31ST MARCH, 1940

RECEIPTS		EXPENDITURE	
	Rs. a. p.		Rs. a. p.
Opening Balance in hand at close of the last financial year ...	1,998 3 9	Establishment ...	1,500 8 6
United Provinces (Government grant (Non-recurring) for 1939-40 ...)	2,000 0 0	Contingency, (Including postage stamps, stationery, and allowances, etc.) ...	531 8 6
Allahabad Municipal Board grant for 1939-40 ...	250 0 0	Printing of Proceedings of the National Academy of Sciences, India ...	1,937 14 6
Subscription from members ...	2,139 0 0	Remuneration paid on Symposium on Problems of Power Supply in India ...	200 0 0
Life-membership subscription ...	498 0 0	Binding of Exchange Journals ...	68 10 0
Sale of Proceedings of the National Academy of Sciences, India ...	51 6 0	Furniture ...	25 0 0
Bank Commission on outside cheques ...	2 8 0	Bank Charges on outside cheques ...	15 4 0
Miscellaneous receipts ...	2 0 0	Investment on P. O. 5-year Cash Certificates (17) ...	1,498 2 0
		Available cash balance on 31st March, 1940, with the Imperial Bank of India, Allahabad ...	1,165 2 3
Total Rs. ...	6,942 1 9	Total Rs. ...	6,942 1 9

Account compiled by :—

P. C. MUKERJI,

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